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THE NATIONAL FIRE-DANGER RATING SYSTEM — 1978

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THE AUTHORS

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Jack D. Cohen received his bachelor's degree in forest science from the University of Montana in 1973 and his master's degree in bioclimatology from Colorado State University in 1976. He did environmental air quality research before joining the National Fire-Danger Rating research work unit at the Northern Forest Fire Laboratory, Missoula, Montana, in May 1976.

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RESEARCH SUMMARY

The 1978 National Fire-Danger Rating System (NFDRS) updates the danger rating system developed in the early 1970's and published by Deeming and others in 1972. Numerous changes have been made to correct deficiencies and to incorporate new technology. The most significant of the changes are:

1. Improving the response to drought.
2. Increasing the sensitivity of the ratings, particularly in the lower fire-danger ranges.
3. Reflecting the effect of changing day length on burning conditions.
4. Improved accounting of fuels through improvement of the existing fuel models and the addition of the 11 more fuel models.
5. Separating the occurrence indexes for man-caused and lightning-caused fires.
6. Developing predictive models for the moisture contents of live grasses and forbs, and woody shrubs.

The results of this work are presented in two publications. This publication covers the general information on the NFDRS and its application; a second publication (Burgan and others 1977) contains the nomograms and directions for calculating fire-danger ratings manually.

CONTENTS

PREFACE

At the time of this writing, the spring of 1977, the 1972 version of the National Fire-Danger Rating System (Deeming and others 1972) is being used by all Federal agencies and 35 State agencies charged with forest and rangeland fire protection. During the summer of 1976, data from more than 800 fire-danger rating stations were processed through the interactive computer program AFFIRMS (Helfman and others 1975; Deeming 1975; Straub 1975) and half again as much data were processed manually each day.

But things have changed since 1972. Knowledge of combustion physics, wildland fuels, and the factors that influence the occurrence of forest and rangeland fires is expanding. And experience with the 1972 NFDRS has highlighted problems in the System that need attention.

All of this was anticipated at the time the 1972 NFDRS was released for field use. Plans were made at that time for an update of the System in 1978 that would correct deficiencies and incorporate new research. That update is documented in this report.

This work was done under the direction of a technical committee chartered in 1974 by the Chief of the Forest Service. The NFDRS Technical Committee membership was of USDA Forest Service research and forest systems personnel, and fire managers from the Bureau of Land Management, and the States of Pennsylvania, North Carolina, and Oregon.

The results of this effort are presented in two publications. This publication covers basic instructions for applying and interpreting the NFDRS. A separate publication, Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System (Burgan and others 1977), is intended for those who do not utilize AFFIRMS. It contains the nomograms and directions for manually calculating fire-danger ratings.

Instructions covering the few procedural changes for AFFIRMS will be distributed to AFFIRMS users as amendments to the AFFIRMS User Guide (Helfman and others 1975).

UPDATING THE NATIONAL FIRE-DANGER RATING SYSTEM

The principal problem areas to be addressed in the updating effort were:

1. The need to improve the response of the NFDRS to drought.
2. The lack of sensitivity of the ratings, particularly in the lower fire-danger ranges.
3. The lack of response of the NFDRS ratings to changing day length.
4. The inadequate representation of fuels by the nine available fuel models.
5. The need to develop a fire occurrence index that would provide the fire manager with reliable information on fire incidence.
6. The need for a better way to assess the condition of the live fuels: grasses, forbs, and woody shrubs.
7. Three slope classes were not sufficient to properly describe the terrain in some areas of the West.

In addition to addressing these specific problems, a more general objective was to incorporate the latest relevant developments in fire modeling, forest fuels, and fire occurrence research. The following section tells briefly how these problems were solved. (See appendix A for definition of abbreviations and terms.)

Response to Drought

Because the largest fuel considered in the 1972 NFDRS has only a 100-hour moisture timelag, the NFDRS indexes and components are not influenced by extended periods of below average precipitation. The initial problem was to determine the avenue by which long-term drying affects fire behavior.

The most obvious response to long-term drying that affects fire behavior is the decrease in moisture content of the live fuels--grasses, forbs, and the twigs and foliage of woody shrub species. In addition, dead fuels up to 6 inches in diameter (1,000-hour timelag class) that do respond to long-term drying were incorporated in those fuel models where it was realistic to do so.

Sensitivity of Ratings

The problem has been solved by not restricting the burning index (BI), energy release component (ERC), and spread component (SC) to 0 to 100 scales. The SC is numerically equal to the theoretical rate of spread in feet per minute; and the ERC is numerically equal to the available energy in Btu's per square foot divided by 25. The BI has been scaled so that it equals 10 times the predicted flame length.

The results have been a fivefold increase in the sensitivity of the SC; the BI is three times as sensitive; and the ERC is about twice as sensitive.

Fuel Models

In the 1972 NFDRS, the user is given a choice of nine fuel models. Many users feel that fuels in their areas are not adequately represented; others, on the other hand, are of the opinion that such a range of choices is not needed to rate fire danger.

The set of fuel models has been increased to 20. Twenty models should adequately represent the fuels that must be dealt with in the United States.

Fire Occurrence Models

Because of the dissimilarities of the causative firebrands and the fuels where the fires typically start, man-caused and lightning-caused fires are considered separately. The structure of the occurrence module has been modified with separate occurrence indexes for man-caused and lightning-caused fires.

The Man-Caused Fire Occurrence Index (MC)I)

The MCOI is derived from the man-caused risk (MCR) and the ignition component (IC). The MCR appears essentially the same as in the 1972 NFDRS. However, it incorporates factors derived from local fire and fire weather records that make the MCOI a much improved indicator of fire occurrence.

Lightning-Caused Fire Occurrence Index (LOI)

The lightning-caused fire occurrence index is derived from lightning risk (LR) and the IC. LR is based on a subjective assessment of lightning and thunderstorm activity and a factor calculated from local records of thunderstorms and lightning fires. The LR scaling factor, as it is called, will fit the predictions of the lightning fire occurrence model to local conditions.

Six lightning activity levels (LAL) are available to choose from. LAL's 1 through 5 are similar to those in the 1972 NFDRS, but the basis for selection has been expanded. LAL 6 was added to flag emergency level lightning fire activity.

Seasonality of Ratings

The 1972 NFDRS tends to overrate fire danger during the early spring, late summer, and fall, particularly in Alaska and the more northern of the lower 48 States. The problem was to account for the seasonal and latitudinal variation of insolation and its effect on the moisture exchange processes.

To this end we have made several changes. Instead of using a simple average of the 24-hour maximum and minimum equilibrium moisture contents in calculating the 100-h TL and 1,000-h TL FM's, an average, weighted by day length, is used to characterize the "drying power" of the day. As the period of daylight shortens, the nighttime conditions are given increasing weight, thus promoting recovery in the predicted moisture content of the heavy fuels.

The fuel moisture analog (half-inch sticks) value is used for the calculation of 10-h TL FM and is now weighted into the calculation of the 1-h TL FM. The analog provides a straightforward solution because the seasonally induced effects are automatically integrated in the fuel stick response.

Insufficient Terrain Definition

In the 1972 NFDRS, three slope classes are used: 0-20 percent, 21-40 percent, and greater than 40 percent. This is not sufficient for mountainous areas where slopes up to 100 percent are commonly encountered. The number of slope classes has been increased to five, with 90 percent the midpoint of slope class 5.

PRINCIPLES OF THE NATIONAL FIRE-DANGER RATING SYSTEM

To use the NFDRS effectively, one must know what it will do and will not do. The basic principles of the NFDRS are as follows:

1. The NFDRS relates only to the potential of the initiating fire. An initiating fire is one that does not behave erratically; it spreads without spotting through continuous ground fuels. Crowning and spotting are not now addressed. However, experience with the NFDRS will enable users to identify the critical levels of fire danger when such behavior is highly probable.

2. The System only addresses those aspects of fire control strategy affected by fire occurrence and behavior. The concept of containment, as opposed to extinguishment, is basic because it allows us to limit the scope of the rating problem to the behavior potential of the headfire. Other aspects of the containment job such as accessibility, soil condition, and resistance to line construction must be evaluated by other means.

3. The ratings are relative, not absolute. Wherever possible, we have structured the component or index so that it is linearly related to the particular aspect of the fire problem being rated. Thus, when the value of a component or index doubles, the fire manager should expect a doubling of the rated activity relative to what has been recently observed. *The BI is an exception that will be addressed later.*

4. Fire danger is rated from a *worst case* approach. Fire weather is measured at the time of day when fire danger is normally the highest; and wherever possible, in the open at midslope on southerly or westerly exposures. This important principle must be understood if fire-danger ratings are to be properly interpreted.

What if a fire occurs before or after the peak of the burning period? Or at a location other than midslope on a southerly aspect? The odds are overwhelmingly against the behavior of a particular fire equaling or exceeding that indicated by the ratings. The fire behavior components computed for a day characterized by normal diurnal patterns of relative humidity, temperature, and wind *define the approximate upper limit of behavior.*

By chance, there will always be fires that exceed the indicators because one observation per day per 100,000 or more acres is a thin sample. Conditions more severe than those represented by the fire weather observation are sure to exist.

The term *average worst*, long heard among fire managers, was first used by Gisborne (1936) and Hayes (1944) to denote the *average* of fire-danger ratings computed from several sets of fire weather data. This average answered the need to combine several sets

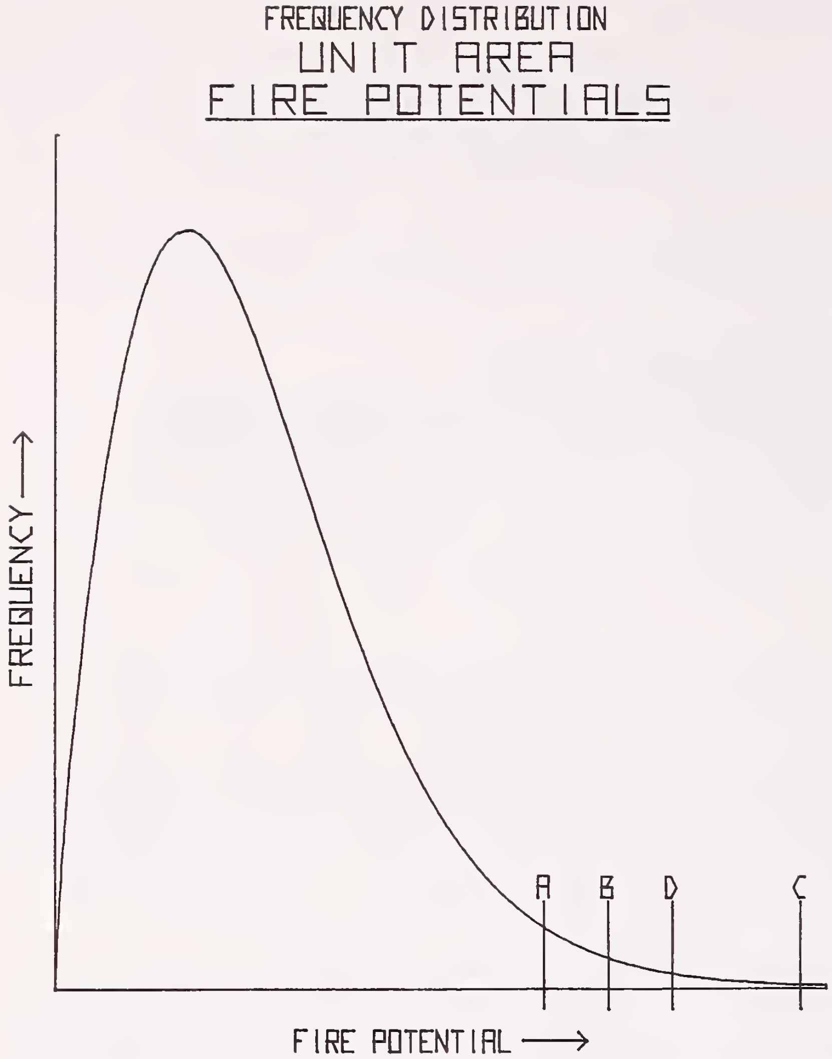

Figure 1.--Theoretical frequency distribution of unit area fire potentials for a 24-hour period. The behavior of fires started randomly over a fire-danger rating area without regard for time of day, slope position, or aspect would be distributed in a manner similar to this curve. Fire-danger stations A, B, and C would indicate relatively high potential because the data are collected in the afternoon on the more severe sites. (D is the average of A, B, and C.) The majority of fires, by far, will behave less severely than fire-danger data indicate.

of data into a single set that the decisionmaker could readily use. What does "average worst" actually mean? If one could compute a set of fire-danger ratings for every acre of a protection unit every half-hour, those ratings would be distributed approximately as in figure 1. Most of the ratings would indicate relatively low fire potential, skewing the distribution toward the low side.

Locate the ratings computed from data taken at three hypothetical fire weather stations A, B, and C at basic observation time. D is the average of A, B, and C, hence defines *average worst*, the level the fire manager would prepare for.

The area under the curve to the right of D represents the probability that a specific fire will burn under conditions more severe than the fire suppression organization is prepared for. A protection agency cannot afford to protect at the level indicated by C, so it must gamble that a fire will not occur under those conditions. Sometimes a fire does occur and the gamble does not pay off.

We do not know the probability of such an event happening. The probability is low, however, because we rate fire danger for the worst possible conditions--on south or southwesterly aspects, and so on.

The main point is this: the NFDRS will not predict how every fire will behave. Other systems fill this need (Albini 1976b; Van Gelder[1]). The NFDRS is intended to provide guidance for short range planning. *It evaluates the near upper limit of the behavior of fires that might occur on a rating area during the rating period.*

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[1] Van Gelder, Randall J. Firecasting--the next generation of fire-danger rating? USDA For. Serv. Res. Note [in preparation]. Pac. Southwest For. and Range Exp. Stn., Berkeley, California.

STRUCTURE OF THE NATIONAL FIRE-DANGER RATING SYSTEM

The System (fig. 2) provides four indexes to aid in planning fire control activities. They are: the man-caused fire occurrence index (MCOI), the lightning-caused fire occurrence index (LOI), the burning index (BI), and the fire load index (FLI).

The MCOI is derived from the man-caused risk (MCR), an assessment of the status of man-caused fire sources in a rating area, and the ignition component (IC), an expression of the likelihood that a firebrand will cause a reportable fire.

The lightning-fire occurrence index (LOI) is similar in concept to the MCOI. It is derived from the IC and lightning risk (LR), an indicator of thunderstorm activity. Both OI's are interpretable in terms of expected numbers of fires on the rating area.

The BI is derived from the spread and energy release components (SC and ERC). The rate of fire spread and the energy released in the flaming zone, considered together, are the means of rating the difficulty of containment. The BI is linearly related to the length of flames at the head of the fire. It is calculated from the SC and ERC using the relationships originally developed by Byram for calculating flame length (Byram 1959, p. 82).

A measure of the difficulty of containing a single fire (the BI), combined with the probable number of fires as projected by the MCOI and LOI, produces a measure of the total potential fire containment job. This is the fire load index (FLI). The FLI is the ultimate index of the NFDRS; it integrates the risk, ignition, and fire behavior potentials as evaluated by the other indexes and components.

The risk ratings (LR and MCR), the fire occurrence ratings (LOI and MCOI), the ignitibility rating (IC), and the fire load index are expressed on scales of 0 to 100 just as in the 1972 NFDRS. The SC, ERC, and BI scales are open-ended; that is, no upper limits have been imposed.

1978 NATIONAL FIRE-DANGER RATING SYSTEM

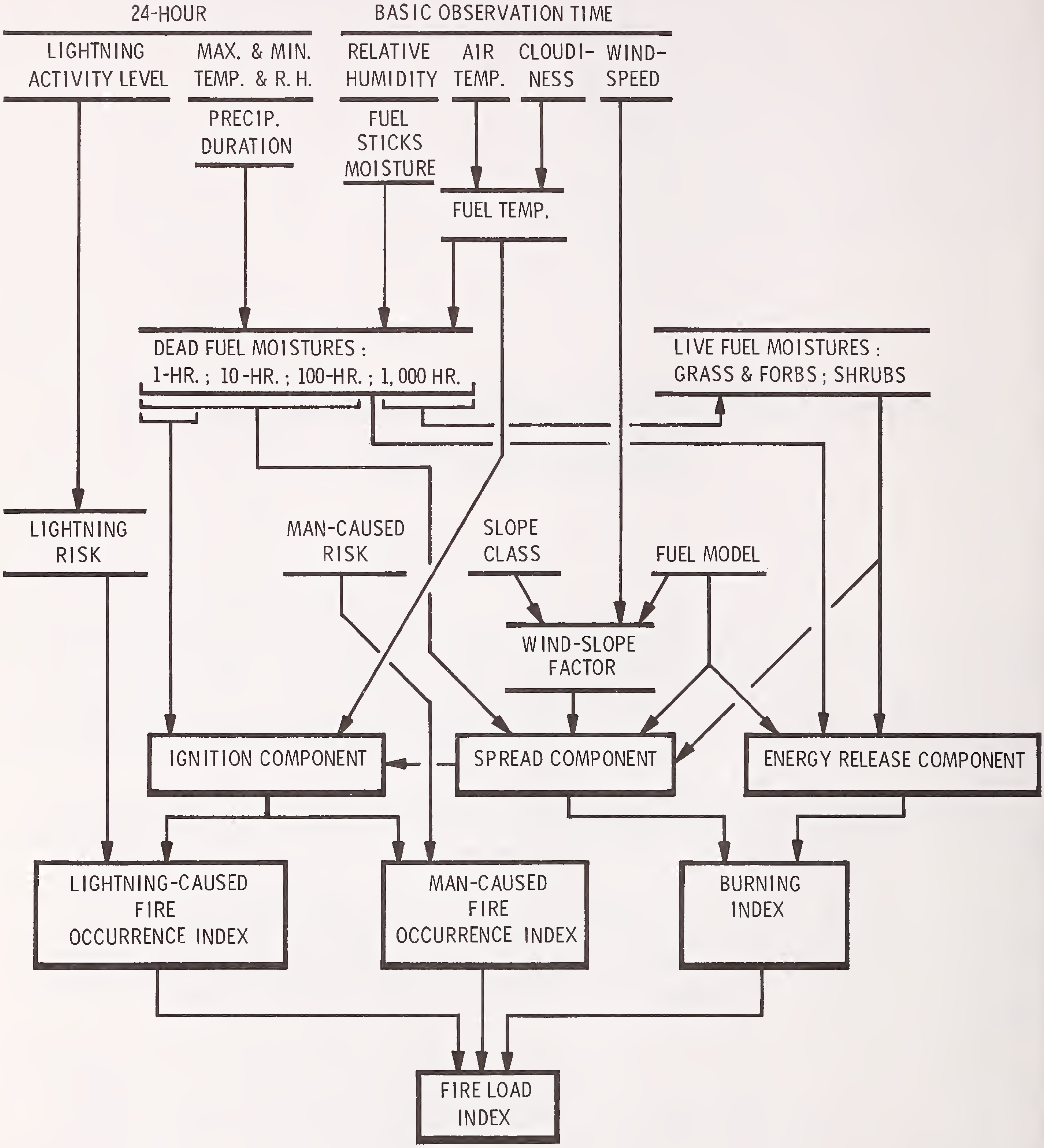

Figure 2.--Structure of the 1978 National Fire-Danger Rating System.

THE NATIONAL FIRE-DANGER RATING SYSTEM COMPONENTS

Risk and the IC, SC, and ERC are the foundation of the NFDRS. These components directly address the problems of integrating the effects of fuels--quantity, arrangement, fuel particle geometry and chemistry--fuel moisture, wind, topography and state of fire-starting agents. Because of their basic importance to the NFDRS, a closer look is warranted. The components can be subdivided into those that deal with fire behavior potential and those that deal with fire occurrence.

Fire Behavior Potential

To successfully rate fire danger, a realistic appraisal of the behavior potential of possible fires is essential. For control planning, the first consideration is rate of spread. The spread component is directed at this need.

A second basic consideration is the potential amount of energy that can be released in a passing fire. This is indicated by the energy release component.

Combined in the BI, these components provide an estimate of potential flame length and fireline intensity.

The Spread Component (SC)

The SC is based on a mathematical fire spread model developed at the Northern Forest Fire Laboratory (Rothermel 1972; Albini 1976a, 1976b). The spread model integrates the effect of wind, slope, and fuel bed and fuel particle properties to predict the forward rate of fire spread. The slope class and the fuel model (fuel model specifies the fuel particle and fuel bed characteristics) are constants in the calculation of the SC. The daily variations of SC are caused by the changes in the wind and moisture contents of the live fuels and the dead fuel timelag classes of 1, 10, and 100 h.

The Energy Release Component (ERC)

The ERC is based on the estimated potential available energy released per unit area in the flaming zone of the fire. The ERC is dependent on the same fuel characteristics as the SC; loading, compaction, particle size (fineness), heat of combustion, and mineral content. The day-to-day variations of the ERC are caused by changes in the moisture contents of the various fuel classes, including the 1,000-h TL class. The ERC is derived from predictions of (1) the rate of heat release per unit area during flaming combustion, and (2) the duration of flaming.

Fire Occurrence

For effective fire suppression and prevention one must estimate not only the behavior of fires *that might occur*, but also the number of fires to expect. In the NFDRS, the MCOI and LOI indicate the expected level of fire incidence.

The occurrence indexes are derived from assessments of the ignitibility of fine fuels and prevalence of ignition sources (firebrands). The IC is a measure of

ignitibility. The two risk components, LR and MCR, are evaluations of the status of lightning and the fire-causing activities of man. Let us look at each in more detail.

The Ignition Component (IC)

The IC is related to the probability of a firebrand producing a fire that will require suppression action. Ignition occurs in four phases: (1) the firebrand comes in contact with the dead fine fuel; (2) the moisture in the fuel particle is driven off; (3) the temperature of the fuel particle is raised to the point where pyrolysis begins--200° to 250°C (390° to 480°F); and (4) ignition occurs when the fuel and the pyrolytic gases are heated to approximately 320°C (610°F).

The probability that a firebrand will ignite fuels is mainly a function of (1) dead fine fuel moisture content--(1-h TL FM); (2) dead fine fuel temperature; (3) the surface area-to-volume ratio (fineness) of the fuel elements; (4) the compactness of the fuel bed; and (5) firebrand characteristics such as temperature, rate of heat released, the length of time it will burn, and whether it is glowing or flaming. For fire-danger rating purposes only the variability of the first two are considered.

The moisture content of the dead component of the fine fuel (1-h TL FM) is governed primarily by the temperature and relative humidity of the air immediately in contact with the fuel particle. In calculating the 1-h TL FM, the temperature and relative humidity measured in the instrument shelter are adjusted to fuel level. The extent of the adjustment is dependent upon the amount of cloudiness (Fosberg and Deeming 1971; Haltiner 1975).

The higher the initial temperature of the fuel, the easier it is to raise the temperature of the fuel particle to the kindling point. Just as in the calculation of the 1-h TL FM, a correction is made to the instrument shelter temperature to approximate the fuel temperature.

The IC must also consider the probability that a successful ignition will evolve into a fire requiring suppression action. Work in the northeastern and southeastern United States has shown that the number of man-caused fires increases as the potential rate of spread increases (Crosby 1954; Haines and others 1970). With the incorporation of the spread component in the 1978 NFDRS ignition component, its validity has been greatly improved.

Lightning Risk (LR)

The LR has been designed to account for more than just the quantity of cloud-to-ground lightning, as was done in the 1972 NFDRS.

Characteristics of regional storms affect the "efficiency" of lightning as a fire starter. For instance, West Coast and Great Plains thunderstorms are "wetter" than those of the Southwest and the Central and Northern Rockies. Another example: the frequency of "hot" cloud-to-ground discharges capable of starting fires appears to be greater in Alaskan storms than in any others.

Local and regional fuels also affect lightning efficiency. The finer the fuel particles and the "fluffier" the fuel bed, the more susceptible the fuel is to ignition by a lightning stroke. For instance, in the Northern Rockies, more fires occur per unit area in ponderosa pine than in any other forest cover type (Barrows 1951; Barrows and others[2]).

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[2] Barrows, J. S., D. V. Sandberg, and J. D. Hart. 1977. Lightning fires in Northern Rocky Mountain forests. Final Rep. Coop. Agreement 16-44-CA, Colorado State Univ. and Intermt. For. and Range Exp. Stn., 210 p. Unpublished report on file at the North. For. Fire Lab., Missoula, Mont.

To measure all regional factors would be an impossible task. Instead, we introduced a statistic derived from local records of thunderstorm and lightning-caused fires, the *lightning risk scaling factor*. Details for its derivation are included in appendix D.

The LR is derived from forecasts or observations of thunderstorm activity (lightning activity level--LAL). The LR associated with an LAL is then "fitted" to local experience by applying the LR scaling factor.

A sixth lightning activity level has been added to those introduced in the 1972 NFDRS. It serves as a "red flag" to denote those extremely dangerous situations that occasionally occur in Alaska and the western States. When an LAL 6 is specified, the LOI is automatically set to 100.

Based on current data, the NFDRS will continue to assume that 25 percent of all lightning-caused fires remain undetected for at least 24 hours.

Man-Caused Risk (MCR)

Procedures for estimating man-caused risk remain similar to those used in the 1972 NFDRS. However, incorporation of a statistic derived from local records of fire weather and man-caused fires has greatly increased the accuracy of fire occurrence prediction (appendix F).

No objective means have been developed for determining the MCR. As in the 1972 NFDRS, it continues to be based on the local fire manager's estimates of the status of fire-causing agents. The scheme is reasonably simple. On a scale of 1 through 5 (*daily activity level*), a rating is assigned to activities that have been important sources (*risk sources*) of man-caused fires in the rating area. The rating scale is calibrated to the level of activity normal for *that day of the week*. If a particular risk source is less active than what is normal for that day of the week, a "None" or "Low" daily activity level may be assigned; if it is more active, a "High" or "Extreme" daily activity level may be assigned.

The contribution that a particular risk source makes to the final MCR value is weighted according to the proportion of the historical man-caused fires occurring on that day of the week that are attributable to that risk source (*risk source ratio*).

The principal risk sources for the fire season are identified by analyzing fire occurrence records.

Although daily activity levels may be similar, actual risk may vary greatly among protection units. Firebrands and fuels differ from one area to another. Also, fire prevention programs and the attitudes of the populace toward fire differ. We deal with these differences as we did with lightning risk: develop a statistic that can account for local factors. The derivation of the *man-caused risk scaling factor* is covered in appendix E.

The procedure for evaluating MCR can be partitioned into two phases. Phase 1 involves analyzing historical fire weather and fire occurrence records to (1) identify risk sources; (2) determine risk source ratios, and (3) derive the MCR scaling factor.

Phase 2 is those tasks that must be done daily. It consists of (1) assigning a daily activity level to each risk source and (2) computing the MCR.

Appendix E covers the procedures in detail and contains worked examples.

FIRE LOAD INDEX (FLI)

Stated again, the FLI is the culminating index of the NFDRS. It is designed to combine the projections of fire occurrence and behavior into a single number that can be related to the total fire control job.

Because fire managers have not agreed on a common denominator for measuring the total job, the equation for calculating the FLI has been developed intuitively. The task of attaching meaning to the FLI has been left to the users. They will have to determine the relationship between the FLI and whatever measure of the total fire control effort they choose.

The FLI ranges over a scale of 0 to 100. A high FLI can be caused by a projection of high fire incidence (LOI + MCOI) *or* severe fire behavior. By itself, the FLI does not tell much about the nature of the fire management problem. To get a complete picture, one has to examine the components and indexes that are the basis for the FLI.

The fire load index is designed as the primary manning index for a major administrative unit such as a county or National Forest. However, the mix of men, ground equipment, and aircraft needed are best indicated by the BI, SC, and ERC.

FUELS IN THE NATIONAL FIRE-DANGER RATING SYSTEM

Classification of Wildland Fuels

Fire danger varies from day to day with changes in risk, wind, and moisture content of fuels. Moisture contents of dead fuels are controlled by environmental factors: relative humidity, precipitation, and temperature. Moisture levels within living plants are primarily controlled by life processes. This distinction is the basis for the first major divisions in the NFDRS fuel classification system--dead and live fuels.

Dead fuels are assigned to subclasses according to the speed or timelag (Lancaster 1970) with which the moisture content of the individual fuel particle responds to precipitation, relative humidity, and temperature. The shorter the timelag, the more responsive the fuel. In the 1972 NFDRS, three dead fuel classes were included: 1-, 10-, and 100-hour timelag. For 1978, a fourth class was added--that of the 1,000-hour timelag fuel. The 1978 NFDRS timelag classes for dead fuels are shown in table 1.

Table 1.--*NFDRS dead fuel classes*

Timelag class	Fuel: Roundwood (diameter)	Fuel: Litter (depth)
	- - - - - - - - - *Inches*	- - - - - - - -
1-hour (0-2 hours)	To 1/4	To 1/4
10-hour (2-20 hours)	1/4 to 1	1/4 to 1
100-hour (20-200 hours)	> 1 to 3	> 1 to 4
1,000-hour (200-2,000 hours)	> 3 to 8	> 4 to 12

Two major classes of living fuels are recognized: (1) grasses and other herbaceous plants and (2) shrubs, specifically the twigs and foliage. The herbaceous plants are subdivided into annuals and perennials. Annual herbaceous plants are shallow rooted and are the first to be affected by drought. The perennials are next, and shrubs, which are the deepest rooted, are the least affected. From the phenological aspect, annuals complete their growth cycle well within a normal growing season. They sprout, grow, produce seed, and die before the first freeze normally occurs. Perennials, on the other hand, normally stay green throughout the growing season and do not cure completely until temperatures in the fall get too low to sustain growth.

Fuel Models

The concept of fuel models was first introduced in the 1972 NFDRS (Deeming and others 1972). That publication, and another by Deeming and Brown (1975), explained the role of fuel models. To review briefly, fuel models were devised as a means for organizing fuels data for input into Rothermel's mathematical fire spread model. The fire spread model requires fuel bed properties such as compactness and loadings by classes of living and dead fuels; and fuel particle properties such as density, geometry, heat content, and mineral content.

Before selecting the fuel and cover types for the fuel mode[illegible] we needed to decide how precise the models had to be to achieve the objectives of f[illegible] danger rating. Recall that the principal objective of the NFDRS is to produce inf[illegible] tion for presuppression planning. The target is large--a fire-danger rating area m[illegible] e tens of thousands of acres in size. And the period is long--from several hours to [illegible] hours. Because wind, fuel moisture, and slope vary so much within such a large area, these factors are more likely to limit the accuracy of the fire-danger projections than the lack of precision in the fuel models.

Since 1972, more has been learned about the physical properties of fuels through research and experience. For 1978, we have increased the number of fuel models from 9 to 20 and have improved the descriptors of the existing models. To make the models more responsive to drought, we have added live fuels and the 1,000-hour timelag fuels where warranted. Only one of the original nine models has been deleted--fuel model F. The original F model has been replaced with a model representing intermediate brush (mature chamise and mixed chaparral less than 6 feet tall). With the exception of the F model, the original nine models have retained the alphabetical designators assigned in the 1972 NFDRS.

Table 2.--*Fuel models for Climate Class 1*

[Fuel moisture:

1-h	10-h	100-h	1000-h	Herb	Woody
2%	4%	6%	7%	Cured	65%

Wind: 20 mi/h, 20 ft (32 km/h, 6 m) Slope class: 1]

Letter desig.	Fuel model	BI	SC	ERC
	Grass type fuels			
A	Annual grass and forbs	102	570	4
	Brush type fuels			
T	Sagebrush grass	116	133	21

Table 3.--*Fuel models for Climate Class 2*

[Fuel moisture:

1-h	10-h	100-h	1000-h	Herb	Woody
3%	5%	7%	9%	Cured	70%

Wind: 20 mi/h, 20 ft (32 km/h, 6 m) Slope class: 1]

Letter desig.	Fuel model	BI	SC	ERC
	Grass type fuels			
A	Annual grass	89	489	3
L	Perennial grass	96	300	6
S	Alaskan tundra	56	24	24
	Brush type fuels			
T	Sagebrush grass	103	118	18
F	Inter. brush	93	54	32
B	Mature chaparral	172	97	69
	Timber type fuels			
C	Open timber/grass	69	45	20

In tables 2, 3, 4, and 5, the fuel models are grouped according to the climate of the areas where they are most likely to apply. The BI, SC, and ERC were computed and tabulated for fairly severe fuel moisture conditions for those climates. For all four groups, the 20-ft windspeed was held constant at 20 mi/h. Slope class 1 was used across the board. *For an explanation of the climate classes, see appendix H.*

The fuel models are grouped in this manner for easy comparison of performance. For example, it would be unrealistic and misleading to compare the performance of the western annual grass fuel model, which should be used only in the desert southwest (climate class 1), to the southern rough fuel model, which is applicable only in the southeast (climate class 3).

Descriptions of the fuel models and instructions for selecting an appropriate fuel model are included in appendix B.

Table 4.--*Fuel models for Climate Class 3*

Fuel moisture:

1-h	10-h	100-h	1000-h	Herb	Woody
4%	6%	8%	11%	65%	75%

Wind: 20 mi/h, 20 ft
(32 km/h, 6 m)

Letter desig.	Fuel model	BI	SC	ERC
	Grass type fuels			
L	Perennial grass	57	178	3
N	Sawgrass	138	167	25
	Brush type fuels			
O	Pocosin	174	99	69
	Timber type fuels			
U	Western, long-needled conifer	55	16	36
P	Southern plantation	48	14	29
D	Southern rough	125	68	48
H	Closed, short-needle conifer (normal dead)	39	8	33
G	Closed, short-needle conifer (heavy dead)	95	30	61
Q	Alaskan black spruce	124	59	56
E	Hardwoods (winter)	65	29	27
R	Hardwoods (summer)	26	6	18
	Slash type fuels			
K	Light slash	89	23	68
J	Medium slash	197	44	201
I	Heavy slash	301	65	343

Table 5.--*Fuel models for Climate Class 4*

Fuel moisture:					
1-h	10-h	100-h	1000-h	Herb	Woody
5%	7%	9%	13%	65%	80%
Wind: 20 mi/h, 20 ft (32 km/h, 6 m)			Slope class: 1		

Letter desig.	Fuel model	BI	SC	ERC
	Timber type fuels			
H	Closed, short-needle conifer (normal dead)	35	7	28
G	Closed, short-needle conifer (heavy dead)	85	27	52
	Slash type fuels			
K	Light slash	80	21	60
J	Medium slash	178	40	179
I	Heavy slash	272	59	304

Fuel Moisture

Live Fuel Moisture Models

One of the more important changes introduced in the 1978 NFDRS is a method to predict seasonal changes in moisture content of annual or perennial herbaceous vegetation and the foliage and small twigs of woody shrubs.

In the 1972 NFDRS, the state of the live lesser fuels (grasses and forbs) was denoted by estimating the live proportion of the fine fuel complex. These estimates were made by directly sampling the fine fuels along a permanent transect. Moisture content of live, woody fuels was estimated by selecting one of three condition states or stages of woody plant development--rapid growth, maturing, or drought stage.

The major difficulty with these approaches is the inconsistency among observers in selecting sampling sites and taking measurements. Assuming accurate measurements, the data may change drastically with transect location. Thus, we need to develop a method that would provide consistent, broadscale estimates of the moisture contents of the live fuel components.

The need to improve the response of the NFDRS rating to drought substantially added to the importance of correctly specifying moisture values for live fuels. Rather than provide an auxiliary drought index, the preferred solution was to cause the ratings to respond to the increased flammability of live plants and heavy dead fuels due to drought. Adding the 1,000-hour timelag class of dead fuels was an obvious advance.

Table 6.--*Minimum percent moisture for live fuels*

Type of season	Grasses and forbs: Annuals	Grasses and forbs: Perennials	Shrubs, twigs, and foliage
Wet	∿30 (Late cure)	>80	>110
Normal	<30 (Normal cure)	50-80	80-110
Dry	<30 (Early cure)	<50	50-80

The first live fuel moisture models were developed by R. C. Rothermel (Northern Forest Fire Laboratory, manuscript in preparation). He derived empirical relationships between the moisture contents of vegetation sampled at several elevations near Missoula, Montana, and the Keetch-Byram drought index (Keetch and Byram 1968). The authors adapted Rothermel's work for the NFDRS, substituting the 1,000-h TL FM for the drought index. (That is why the 1,000-h TL FM must be calculated even for fuel models that do not include 1,000-h TL fuels.)

The live fuel models were calibrated to produce reasonable fuel moisture values for both herbaceous and woody vegetation. The performance objectives for the live fuel models are summarized in table 6.

The user has considerable control over the responses of the live fuel moisture models through his selection of climate class and the type of lesser vegetation--annual or perennial.

Climate classes adjust the response of the live fuel moisture prediction models to environmental conditions. Plants native to high precipitation areas react differently to a rainfall anomaly of a given magnitude than do plants native to arid areas.

Designating the lesser vegetation as annual or perennial is extremely important. The live fuel moisture model will predict faster drying and curing rates for annuals than for perennials.

Instructions for selecting the climate class and using the live fuel moisture models are covered in appendix H.

Dead Fuel Moisture Models

The methods for calculating the moisture content of the dead fuel classes are essentially the same as those used in the 1972 NFDRS and are based on the similar theory and procedures (Fosberg 1970 and 1971; Fosberg and Deeming 1971). The key parameters are the equilibrium moisture content (U.S. Forest Products Laboratory 1974) and precipitation duration (Fosberg 1972).

The 1,000-h TL FM model is a simple extension of the 100-h TL FM model. The drying (or wetting) factor must be calculated for each 24 hours, using the maximum and minimum temperatures and relative humidities, and the precipitation duration. The 1,000-h TL FM is calculated from a running 7-day average of the daily factors and the 1,000-h TL FM at the beginning of the 7-day period.

Refinements have been made to the 100-h TL FM model to simplify the calculations and adjust its response to precipitation and changes in day length. The results are lower values in midsummer and higher values in midwinter than you would obtain using the 1972 method.

The new method of calculating the 10-h TL FM is more complex than that used in the 1972 NFDRS. The answer is dependent upon the previous day's value of the 10-h TL FM, the 24-hour extremes of temperatures, and relative humidity and precipitation. Precipitation duration must still be considered in two periods--the first 16 hours and the last 8 hours of the 24 hours between observations.

To account for day length and the lingering influence of wet soil on the ground fuels after rain, the 1-h TL FM model has been changed. The solution was borrowed from the Wildland Fire-Danger Rating System used in California from 1958 to 1972 (U.S. Department of Agriculture, Forest Service 1958).

In the new model, the 1-h TL FM is a weighted average of the fuel stick moisture content and the equilibrium moisture content calculated from the observation time temperature and relative humidity. The fuel sticks integrate the effects of day length and cloudiness. Because they are exposed near the ground, the sticks reflect the influence of soil moisture on the relative humidity at ground level. During extended dry periods in midsummer, the results of the 1-h TL FM calculation will be very close to those obtained using the 1972 method.

THE FIRE WEATHER OBSERVATION

The recording of weather data should be started at least 4 weeks before the fire season. This lead time is needed to stabilize the predictions of 1,000-h TL and live fuel moistures. Values for the 100-h TL FM and the 1,000-h TL FM at the time observations are begun are normally 30 percent moisture content (McCammon 1976). But, a lower or higher starting value can be used if you have information from comparable sites in the vicinity. Accurate starting values are not needed, however, if the 4-week rule is adhered to. After 4 weeks the predictions will be close to the real answers regardless of the starting value.

The NFDRS requires more weather information than fire-danger rating systems that predate 1972. This includes 24-hour maximum and minimum relative humidities and temperatures, and rainfall duration.

Estimates of the beginning and ending times and the duration of rainfall are considered adequate. The 24-hour extreme value for temperature and relative humidity can be obtained from a hygrothermograph. If a hygrothermograph is not available, the maximum and minimum relative humidities can be estimated to acceptable accuracy when the 24-hour temperature extremes are known (Burgan and others 1977, appendix A).

Fuel moisture sticks should be used to determine the 10-h TL FM. Because the dry stick weight changes over time, a correction for stick age must be applied (appendix I). For those who do not use fuel moisture sticks, less reliable methods of estimating the 10-h TL FM are available. The AFFIRMS program can be instructed to calculate the 10-h TL FM from maximum and minimum relative humidities and temperatures, and rainfall durations. Instructions and nomograms for the alternate method of estimating the 10-h TL FM are contained in *Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System* (Burgan and others 1977, appendix B).

Regarding the condition of live fuels--the user must record when greenup occurs, whether it is the initial spring flush or a midseason event as sometimes occurs in arid areas. It is also necessary to indicate when the fine fuels have completely cured (appendix H).

The following list summarizes inputs into the NFDRS. These data should be recorded on the 10-day Fire Danger and Fire Weather Record (appendix J), or on the AFFIRMS recording form.

Station number
Station elevation
Fuel model (appendix B)
Herbaceous vegetation--annual or perennial (appendix H)
Slope class (appendix C)
Date (year, month, day)
State of weather
Herbaceous vegetation condition (appendix H)
Dry and wet bulb temperatures
Lightning risk (appendix D)
Man-caused risk (appendix E)
Windspeed (10-minute average)
Wind direction
Precipitation kind
Precipitation amount
Precipitation duration
Precipitation, beginning and ending times
Lightning activity level (appendix D)
24-hour maximum and minimum temperatures
24-hour maximum and minimum relative humidities
10-hour timelag fuel moisture (appendix I)

The information on the cover of the National Weather Service Form 10-Day Fire Danger and Fire Weather Record, should be reviewed carefully. It covers the proper procedures for taking a fire weather observation.

The fire weather station should be set up in strict accordance with the directions outlined by Fischer and Hardy (1976). An inexpensive triple-beam balance can be substituted for the fuel moisture scales. If a hygrothermograph is not available, use a maximum/minimum thermometer.

THE FIRE WEATHER FORECAST

The fire weather forecaster has been asked to predict the values of those weather elements that will govern the fire danger at a future time, normally the next afternoon. Those predictions should be processed through the National Fire-Danger Rating System to obtain the necessary components and indexes. If you subscribe to the AFFIRMS program, this is done automatically. You can retrieve the fire-danger ratings computed from the the forecasted elements directly from the computer. If you calculate the fire-danger ratings manually, you will have to maintain a set of 10-day fire danger and weather records for recording and processing the fire weather forecast. The procedures will be identical to those followed in calculating the fire-danger ratings from observed weather data, with one exception. If the fire weather forecaster does not predict the 10-h TL FM directly, you will have to make the calculation using the manual procedure (Burgan and others 1977, appendix B) *even if you use fuel sticks.*

A file of the fire danger and fire weather recording forms used for processing the fire weather forecast will provide you with the necessary data for verifying the adequacy of your fire weather service.

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APPENDIX A

ABBREVIATIONS

BI	- Burning index
ERC	- Energy release component
FLI	- Fire load index
IC	- Ignition component
LAL	- Lightning activity level
LOI	- Lightning-caused fire occurrence index
LR	- Lightning risk
MCOI	- Man-caused fire occurrence index
MCR	- Man-caused risk
NFDRS	- National Fire-Danger Rating System
SC	- Spread component
TL	- Timelag
1-h TL FM	- 1-hour timelag fuel moisture content
10-h TL FM	- 10-hour timelag fuel moisture content
100-h TL FM	- 100-hour timelag fuel moisture content
1,000-h TL FM	- 1,000-hour timelag fuel moisture content

GLOSSARY

AMBIENT.--Surrounding, enveloping conditions. As it pertains to weather at the earth's surface, the conditions measured in the instrument shelter are considered ambient.

ANALOG.--See fuel moisture analog.

ANNUAL.--A plant that lives for one growing season, starting from a seed each year.

AVERAGE RELATIVE HUMIDITY.--The arithmetic average of the maximum and minimum relative humidities measured at a fire-danger station from one basic observation time to the next.

AVERAGE TEMPERATURE.--The arithmetic average of the maximum and minimum dry-bulb temperatures measured at a fire-danger station from one basic observation time to the next.

BASE AREA.--An area representative of the major fire problem on a protection unit. From the base area, the base fuel model and slope class are chosen.

BASE FUEL MODEL.--The fuel model that best represents the fuels on the base area.

BASE OBSERVATION TIME.--The time established to take the fire-danger observation. It should be at that time of day when the fire danger is normally the highest.

BOUNDARY LAYER.--The air in immediate contact with a fuel element.

BOUNDARY CONDITIONS.--The temperature and relative humidity of the boundary layer.

BOUNDARY VALUE.--The EMC commensurate with the boundary conditions and precipitation events of the preceding 24 hours.

BRUSH.--Scrub vegetation and stands of tree species that do not produce merchantable timber. (NOT a synonym for slash.)

BURNING INDEX (BI).--A number related to the contribution of fire behavior to the effort of containing a fire.

CONTAINMENT.--The completion of a control line around a fire and any associated spot fires which can reasonably be expected to check the fire's spread.

CONTROL.--The completion of a control line around a fire and any associated spot fires, which can reasonably be expected to hold under foreseeable conditions. Control implies that the line has been burned out and all hot spots that threaten the line have been eliminated.

DAILY ACTIVITY LEVEL (DAL).--A subjective estimate of the status of a man-caused fire risk source relative to what is normally experienced on that day of the week. Five activity levels are defined: None, Low, Normal, High, and Extreme.

DEAD FUELS.--Naturally occurring fuels whose moisture content is governed by relative humidity and precipitation.

DEW POINT.--The temperature at which a parcel of air being cooled reaches saturation (100 percent relative humidity).

DIURNAL.--Pertains to daily cycles of temperature, relative humidity, and wind.

DROUGHT.--A period characterized by a serious moisture deficiency, extensive in area and time.

DRY-BULB TEMPERATURE.--The temperature of the air.

DUFF.--The partially decomposed organic material of the forest floor that lies beneath the freshly fallen twigs, needles, and leaves. (The F and H layers of the forest floor.)

EMC.--See equilibrium moisture content.

ENERGY RELEASE COMPONENT (ERC).--A number related to the available energy (Btu) per unit area (square foot) within the flaming front at the head of a fire.

EXPECTED NUMBER OF FIRES.--The number of fires that will occur *on the average* over numerous days with the same LOI or MCOI. In probability terminology, "expected" means the average of the results of a large number of trials made under identical circumstances.

EQUILIBRIUM MOISTURE CONTENT (EMC).--The moisture content that a fuel particle will attain if exposed for an infinite period in an environment of specified constant temperature and humidity. When a fuel particle has reached its EMC, the net exchange of moisture between it and its environment is zero.

EXTINCTION MOISTURE CONTENT.--The fuel moisture content, weighted over all the fuel classes, at which the fire will not spread.

FINE FUELS.--The complex of living and dead herbaceous plants and dead woody plant materials less than one-fourth inch in diameter.

FINE FUEL MOISTURE (FFM).--An adjustment to the 1-h TL FM that compensates for the presence of living plant material and the moisture content of that material. The FFM is used in the manual calculation of fire-danger ratings. It replaces the 1-h TL FM and the herbaceous fuel moisture.

FIREBRAND.--Any source of heat, natural or manmade, that is capable of igniting natural fuels.

FIRE-DANGER RATING AREA.--A geographical area within which the fire danger can be assumed to be uniform. It is relatively homogeneous in climate, fuels, and topography.

FIRELINE INTENSITY.--The rate of heat release per unit length of fire front. The most commonly used units in current fire literature are Btu/sec/ft.

FIRE LOAD INDEX (FLI).--A rating of the maximum effort required to contain all probable fires occurring within a rating area during the rating period.

FLAMING FRONT.--That zone of a moving fire where the combustion is primarily flaming. Behind the flaming front the combustion is primarily glowing or involves the burning out of larger fuels (greater than about 3 inches in diameter).

FORB.--A nongrasslike herbaceous plant.

FORECAST AREA.--The geographical area for which a fire weather forecast is specified.

FUEL CLASS.--A group of fuels possessing common characteristics. In the NFDR, dead fuels are grouped according to their timelag (1-, 10-, 100-, and 1,000-h TL). And living fuels are grouped by whether they are herbaceous (annual or perennial) or woody.

FUEL MODEL.--A simulated fuel complex for which all the fuel descriptors required by the mathematical fire spread model have been specified.

FUEL MOISTURE (FM).--See fuel moisture content.

FUEL MOISTURE ANALOG.--A device that emulates the moisture response of specific classes of dead fuels. Examples are basswood slats that represent the 1-h TL fuels and half-inch ponderosa pine dowels that represent the 10-h TL fuels. An analog may also be constructed of inorganic materials.

FUEL MOISTURE CONTENT (ALSO FUEL MOISTURE) (FM).--The water content of a fuel particle expressed as a percent of the ovendry weight of the fuel particle.

HERB.--A plant that does not develop woody, persistent tissue but is relatively soft or succulent and sprouts from the base (perennials) or develops from seed (annuals) each year. Included are grasses, forbs, and ferns.

HERBACEOUS FUELS.--Undecomposed material, living or dead, derived from herbaceous plants.

HERBACEOUS VEGETATION MOISTURE CONTENT.--The water content of a live herbaceous plant expressed as a percent of the ovendry weight of the plant.

HOLDOVER FIRES (ALSO SLEEPER FIRES).--Fires set by lightning but not discovered during the first burning period. In the NFDRS it is assumed that 25 percent of the fires are not discovered until succeeding burning periods.

HUMIDITY.--A measure of the water-vapor content of the air.

IGNITION COMPONENT (IC).--A rating of the probability that a firebrand will cause a fire requiring suppression action.

INITIATING FIRE.--A fire that has recently started and is not crowning or spotting.

INSOLATION.--Solar radiation received at the earth's surface.

INSTRUMENT SHELTER (ALSO THERMOSCREEN).--A naturally or artificially ventilated structure used to shield temperature-measuring instruments from direct sunshine and precipitation.

LESSER LIVE FUELS.--Grasses and forbs; low nonwoody plants, annual and perennial.

LIGHTNING ACTIVITY LEVEL (LAL).--A numerical rating of 1 to 6, keyed to the start of thunderstorms and the frequency and character of cloud-to-ground lightning, forecasted or observed on a rating area during the rating period.

LIGHTNING FIRE OCCURRENCE INDEX (LOI).--A numerical rating of the potential occurrence of lightning-caused fires.

LIGHTNING RISK (LR).--A number related to the expected number of cloud-to-ground lightning discharges capable of starting fires that a rating area will be exposed to during the rating period.

LIGHTNING RISK SCALING FACTOR.--A factor derived from local thunderstorm and lightning-caused fire records that adjusts the predictions of the basic lightning fire occurrence model to local experience. It accounts for factors not addressed directly by the model such as susceptibility of local fuels to ignition by lightning, fuel continuity, topography, and regional characteristics of thunderstorms.

LITTER.--The top layer of the forest floor, typically composed of loose debris such as branches, twigs, and recently fallen leaves or needles; little altered in structure by decomposition. (The L layer of the forest floor.)

LIVING FUELS.--Naturally occurring fuels whose moisture content is controlled by physiological processes within the living plant. The NFDRS considers only herbaceous plants and woody plant material small enough (leaves and needles, and twigs) to be consumed in the flaming front of a fire.

MAN-CAUSED RISK.--A number related to the expected number of man-produced firebrands capable of starting fires that a rating area will be exposed to during the rating period.

MAN-CAUSED RISK SCALING FACTOR.--A number relating man-caused fire incidence to the IC on a rating area. The factor is a statistic based on 3 to 5 years of fire occurrence and fire weather data that adjusts the prediction of the basic man-caused fire occurrence model to fit local experience.

MOISTURE OF EXTINCTION.--See extinction moisture content.

NORMALIZATION.--The process of bringing into accord with a norm or standard.

1-HOUR TIMELAG FUELS.--Fuels consisting of dead herbaceous plants and roundwood less than one-fourth inch in diameter. Also included is the uppermost layer of litter on the forest floor.

1-HOUR TIMELAG FUEL MOISTURE (1-h TL FM).--The moisture content of the 1-hour timelag fuels.

100-HOUR TIMELAG FUELS.--Dead fuels consisting of roundwood in the size range of 1 to 3 inches in diameter and, very roughly, the forest floor from three-fourths inch to 4 inches below the surface.

100-HOUR TIMELAG FUEL MOISTURE (100-h TL FM). The moisture content of the 100-hour timelag fuels.

1,000-HOUR TIMELAG FUELS.--Dead fuels consisting of roundwood 3 to 8 inches in diameter or the layer of the forest floor more than about 4 inches below the surface, or both.

1,000-HOUR TIMELAG FUEL MOISTURE (1,000-h TL FM).--The moisture content of the 1,000-hour timelag fuels.

PARTIAL RISK.--The contribution of a specific source to the man-caused risk. The partial risk is derived from the daily activity level assigned a risk source and its risk source ratio.

PERENNIAL.--A plant that lives for more than two growing seasons. For fire-danger rating purposes, biennial plants are classed with perennials.

PRECIPITATION.--Any or all the forms of atmospheric water, liquid or solid, that reach the ground. (Usually measured to the nearest one-hundredth of an inch.)

PRECIPITATION DURATION.--The time, in hours and fraction of hours, that a precipitation event lasts. More precisely, for fire-danger rating purposes, it is the length of time that fuels are subjected to liquid water during the day.

PROBABILITY.--A numerical rating on a scale of 0 to 1 that a specific event will occur. A "1" translates to perfect certainty that the event will occur; a "0" that it will not.

RATING AREA.-See fire-danger rating area.

RATING PERIOD.--The period of time for which a fire-danger rating value is considered representative. Normally it is the calendar day, midnight to midnight.

RELATIVE HUMIDITY (RH).--The ratio of the actual amount of water vapor in the air to the amount necessary to saturate the air at that temperature and pressure. It is expressed as a percentage.

RESIDENCE TIME.--(1) The time required for the flaming zone of a fire to pass a stationary point; (2) the width of the flaming zone divided by the rate of spread of the fire.

RISK SOURCE.--An identifiable human activity that historically has been a major cause of wildfires on a protection unit. It is one of the eight general causes listed on the standard fire report.

RISK SOURCE RATIO.--The portion of the man-caused fires that have occurred on a protection unit chargeable to a specific risk source. A risk source ratio is calculated for each day of the week for each risk source.

ROUNDWOOD.--Boles, stems, or limbs of woody material; that portion of the dead wildland fuels which are roughly cylindrical in shape.

SHRUB.--A woody perennial plant differing from a perennial herb by its persistent and woody stem; and from a tree by its low stature and habit of branching from the base.

SLASH.--Branches, bark, tops, cull logs, uprooted stumps, and broken or uprooted trees left on the ground after logging; also debris resulting from thinnings or wind.

SLOPE.--Rise or fall (in feet) per 100 feet of horizontal measurement, expressed as a percentage.

SLOPE CLASS.--A code designating the most common slope in the base area. There are five classes: 0-25, 26-40, 41-55, 56-75, and greater than 75 percent.

SURFACE AREA-TO-VOLUME RATIO.--The ratio of the area of the surface of a fuel particle (square feet) to its volume (cubic feet). The higher the ratio, the "finer" the particle; for example, for grasses this ratio ranges above 2,000; for a half-inch fuel moisture stick it is 109.

SPREAD COMPONENT (SC).--A rating of the forward rate of spread of a head fire.

STANDARD DRYING DAY.--A day producing the same net drying as a 24-hour period where the dry bulb temperature is maintained at 80° F and the relative humidity at 20 percent.

STATE OF WEATHER.--A code entered in column 2 of the 10-Day Fire Danger Weather Record Form that indicates the amount of cloud cover, kind of precipitation, and/or restrictions to visibility at the fire-danger station at basic observation time.

10-HOUR TIMELAG FUELS.--Dead fuels consisting of roundwood one-fourth to 1 inch in diameter and, very roughly, the layer of litter extending from just below the surface to three-fourths inch below the surface.

10-HOUR TIMELAG FUEL MOISTURE (10-h TL FM).--The moisture content of the 10-hour timelag roundwood fuels.

THERMOSCREEN.--See Instrument Shelter.

TIMELAG (TL).--The time necessary for a fuel particle to lose approximately 63 percent of the difference between its initial moisture content and its equilibrium moisture content.

UNNORMALIZED MAN-CAUSED RISK.--The sum of the partial risks computed for the risk sources active on a protection unit.

VOLATILES.--Readily vaporized organic materials which, when mixed with oxygen, are easily ignited.

WET-BULB TEMPERATURE.--The temperature of a properly ventilated wet-bulb thermometer.

WINDSPEED.--Wind, in miles per hour, measured at 20 feet above the ground or the average height of the vegetative cover, and averaged over *at least* a 10-minute period.

APPENDIX B

SELECTION OF FUEL MODELS

Ideally, a protection unit should be subdivided into fire-danger rating areas of relatively homogeneous climate, fuels, and topography. Fire-danger rating values would be calculated for each rating area; a weighted average of these numbers would then determine the readiness plan for the protection unit.

At the present time, however, the protection unit is usually the smallest geographical division recognized. The protection unit may be quite homogeneous and satisfy the criteria for a fire-danger rating area. Most units, however, do not. For the calculation of the fire-danger ratings needed to manage fire suppression activities on such units, the fire manager must select an area he considers representative of the fire problem on the unit. We will call this area the *base area*--not to be confused with a fire-danger rating area.

Several options may be considered in selecting the base area:

1. It might be where most fires occur.
2. Where fires are most often fought.
3. Where the potential cost of suppression plus loss of resource and improvement is greatest.

Regardless of the option chosen, a careful study of the protection unit's fire history is essential.

The next step is to select the fuel model that best represents the fuels in the base area. Twenty fuel models are available to choose from. However, it is unlikely that more than two or three will be appropriate for any one protection unit.

The following key and narrative descriptions should help in selecting the correct fuel model.

With the exception of Model F, the fuel models carried over from the 1972 NFDRS have retained their letter designations. The 1972 NFDRS Fuel Model F was seldom used, so for 1978, the F designator was assigned to the intermediate brush fuel model.

FUEL MODEL KEY

I. Mosses, lichens, and low shrubs predominate ground fuels.

A. An overstory of conifers occupies more than one-third of the site.. MODEL Q

B. There is no overstory, or it occupies less than one-third of the site (tundra)... MODEL S

II. Marsh grasses and/or reeds predominate.................................. MODEL N

III. Grasses and/or forbs predominate.

A. There is an open overstory of conifer and/or hardwood trees........ MODEL C

B. There is no overstory.

1. Woody shrubs occupy more than one-third, but less than two-thirds of the site.. MODEL T

2. Woody shrubs occupy less than one-third of the site.

a. The grasses and forbs are primarily annuals................ MODEL A

b. The grasses and forbs are primarily perennials............ MODEL L

IV. Brush, shrubs, tree reproduction or dwarf tree species predominate.

A. Average height of woody plants is 6 ft or greater.

1. Woody plants occupy two-thirds or more of the site.

a. One-fourth or more of the woody foliage is dead.

(1) Mixed California chaparral.......................... MODEL B

(2) Other types of brush.................................. MODEL F

b. Up to one-fourth of the woody foliage is dead............. MODEL Q

c. Little dead foliage.. MODEL O

2. Woody plants occupy less than two-thirds of the site.......... MODEL F

B. Average height of woody plants is less than 6 ft.

1. Woody plants occupy two-thirds or more of the site.

a. Western United States...................................... MODEL F

b. Eastern United States...................................... MODEL O

2. Woody plants occupy less than two-thirds but greater than one-third of the site.

a. Western United States...................................... MODEL T

b. Eastern United States...................................... MODEL D

3. Woody plants occupy less than one-third of the site.

a. The grasses and forbs are primarily annuals................ MODEL A

b. The grasses and forbs are primarily perennial............. MODEL L

V. Trees predominate.

A. Deciduous broadleaf species predominate.

1. The area has been thinned or partially cut, leaving slash as the major fuel component.................................... MODEL K

2. The area has not been thinned or partially cut.

   a. The overstory is dormant; the leaves have fallen........... MODEL E
   b. The overstory is in full leaf.............................. MODEL R

B. Conifer species predominate.

1. Lichens, mosses, and low shrubs dominate as understory fuels... MODEL Q
2. Grasses and forbs are the primary ground fuels................. MODEL C
3. Woody shrubs and/or reproduction dominate as understory fuels.

   a. The understory burns readily.

      (1) Western United States................................. MODEL T
      (2) Eastern United States.

         (a) The understory is more than 6 ft tall............. MODEL O
         (b) The understory is less than 6 ft tall............. MODEL D

   b. The understory seldom burns............................... MODEL H

4. Duff and litter, branchwood, and tree boles are the primary ground fuels.

   a. The overstory is overmature and decadent; there is a heavy accumulation of dead tree debris.......................... MODEL G
   b. The overstory is not decadent; there is only a nominal accumulation of debris.

      (1) The needles are 2 inches or more in length (most pines).

         (a) Eastern United States............................ MODEL P
         (b) Western United States............................ MODEL U

      (2) The needles are less than 2 inches long............... MODEL H

VI. Slash is the predominant fuel.

A. The foliage is still attached; there has been little settling.

1. The loading is 25 tons/acre or greater........................ MODEL I
2. The loading is less than 25 tons/acre but more than 15 tons/acre.. MODEL J
3. The loading is less than 15 tons/acre......................... MODEL K

B. Settling is evident; the foliage is falling off; grasses, forbs, and shrubs are invading the areas.

1. The loading is 25 tons/acre or greater........................ MODEL J
2. The loading is less than 25 tons/acre......................... MODEL K

FUEL MODEL A

This fuel model represents western grasslands vegetated by annual grasses and forbs. Brush or trees may be present but are very sparse, occupying less than one-third of the area. Examples of types where Fuel Model A should be used are cheatgrass and medusahead. Open pinyon-juniper, sagebrush-grass, and desert shrub associations may appropriately be assigned this fuel model if the woody plants meet the density criteria. The quantity and continuity of the ground fuels vary greatly with rainfall from year to year.

FUEL MODEL B

Mature, dense fields of brush 6 feet or more in height are represented by this fuel model. One-fourth or more of the aerial fuel in such stands is dead. Foliage burns readily. Model B fuels are potentially very dangerous, fostering intense, fast-spreading fires. This model is for California mixed chaparral generally 30 years or older. The F model is more appropriate for pure chamise stands. The B model may also be used for the New Jersey pine barrens.

FUEL MODEL C

Open pine stands typify Model C fuels. Perennial grasses and forbs are the primary ground fuel but there is enough needle litter and branchwood present to contribute significantly to the fuel loading. Some brush and shrubs may be present but they are of little consequence. Situations covered by Fuel Model C are open, longleaf, slash, ponderosa, Jeffrey, and sugar pine stands. Some pinyon-juniper stands may qualify.

FUEL MODEL D

This fuel model is specifically for the palmetto-gallberry understory-pine overstory association of the southeast coastal plains. It can also be used for the so-called "low pocosins" where Fuel Model O might be too severe. This model should only be used in the Southeast because of a high moisture of extinction.

FUEL MODEL E

Use this model after leaf fall for hardwood and mixed hardwood-conifer types where the hardwoods dominate. The fuel is primarily hardwood leaf litter. The oak-hickory types are best represented by Fuel Model E, but E is an acceptable choice for northern hardwoods and mixed forests of the Southeast. In high winds, the fire danger may be underrated because rolling and blowing leaves are not accounted for. In the summer after the trees have leafed out, Fuel Model E should be replaced by Fuel Model R.

FUEL MODEL F

Fuel Model F is the only one of the 1972 NFDRS Fuel Models whose application has changed. Model F now represents mature closed chamise stands and oakbrush fields of Arizona, Utah, and Colorado. It also applies to young, closed stands and mature, open stands of California mixed chaparral. Open stands of pinyon-juniper are represented; however, fire activity will be overrated at low windspeeds and where there is sparse ground fuels.

FUEL MODEL G

Fuel Model G is used for dense conifer stands where there is a heavy accumulation of litter and downed woody material. Such stands are typically overmature and may also be suffering insect, disease, wind, or ice damage--natural events that create a very

heavy buildup of dead material on the forest floor. The duff and litter are deep and much of the woody material is more than 3 inches in diameter. The undergrowth is variable, but shrubs are usually restricted to openings. Types meant to be represented by Fuel Model G are hemlock-Sitka spruce, Coast Douglas-fir, and windthrown or bug-killed stands of lodgepole pine and spruce.

FUEL MODEL H

The short-needled conifers (white pines, spruces, larches, and firs) are represented by Fuel Model H. In contrast to Model G fuels, Fuel Model H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels. Fires in H fuels are typically slow spreading and are dangerous only in scattered areas where the downed woody material is concentrated.

FUEL MODEL I

Fuel Model I was designed for clearcut conifer slash where the total loading of materials less than 6 inches in diameter exceeds 25 tons/acre. After settling and the fines (needles and twigs) fall from the branches, Fuel Model I will overrate the fire potential. For lighter loadings of clearcut conifer slash, use Fuel Model J, and for light thinnings and partial cuts where the slash is scattered under a residual overstory, use Fuel Model K.

FUEL MODEL J

This model complements Fuel Model I. It is for clearcuts and heavily thinned conifer stands where the total loading of materials less than 6 inches in diameter is less than 25 tons/acre. Again, as the slash ages, the fire potential will be overrated.

FUEL MODEL K

Slash fuels from light thinnings and partial cuts in conifer stands are represented by Fuel Model K. Typically the slash is scattered about under an open overstory. This model applies to hardwood slash and to southern pine clearcuts where the loading of all fuels is less than 15 tons/acre.

FUEL MODEL L

This fuel model is meant to represent western grasslands vegetated by perennial grasses. The principal species are coarser and the loadings heavier than those in Model A fuels. Otherwise the situations are very similar; shrubs and trees occupy less than one-third of the area. The quantity of fuel in these areas is more stable from year to year. In sagebrush areas Fuel Model T may be more appropriate.

FUEL MODEL N

This fuel model was constructed specifically for the sawgrass prairies of south Florida. It may be useful in other marsh situations where the fuel is coarse and reedlike. This model assumes that one-third of the aerial portion of the plants is dead. Fast-spreading, intense fires can occur even over standing water.

FUEL MODEL O

The O fuel model applies to dense, brushlike fuels of the Southeast. O fuels, except for a deep litter layer, are almost entirely living in contrast to B fuels. The foliage burns readily except during the active growing season. The plants are typically over 6 feet tall and are often found under an open stand of pine. The high

pocosins of the Virginia, North and South Carolina coasts are the ideal of Fuel Model O. If the plants do not meet the 6-foot criteria in those areas, Fuel Model D should be used.

FUEL MODEL P

Closed, thrifty stands of long-needled southern pines are characteristic of P fuels. A 2- to 4-inch layer of lightly compacted needle litter is the primary fuel. Some small diameter branchwood is present but the density of the canopy precludes more than a scattering of shrubs and grass. Fuel Model P. has the high moisture of extinction characteristic of the Southeast. The corresponding model for other long-needled pines is U.

FUEL MODEL Q

Upland Alaskan black spruce is represented by Fuel Model Q. The stands are dense but have frequent openings filled with usually inflammable shrub species. The forest floor is a deep layer of moss and lichens, but there is some needle litter and small-diameter branchwood. The branches are persistent on the trees, and ground fires easily reach into the tree crowns. This fuel model may be useful for jack pine stands in the Lake States. Ground fires are typically slow spreading, but a dangerous crowning potential exists. Users should be alert to such events and note those levels of SC and BI when crowning occurs.

FUEL MODEL R

This fuel model represents the hardwood areas after the canopies leaf out in the spring. It is provided as the off-season substitute for E. It should be used during the summer in all hardwood and mixed conifer-hardwood stands where more than half of the overstory is deciduous.

FUEL MODEL S

Alaskan or alpine tundra on relatively well-drained sites is the S fuel. Grass and low shrubs are often present, but the principal fuel is a deep layer of lichens and moss. Fires in these fuels are not fast spreading or intense, but are difficult to extinguish.

FUEL MODEL T

The bothersome sagebrush-grass types of the Great Basin and the Intermountain West are characteristic of T fuels. The shrubs burn easily and are not dense enough to shade out grass and other herbaceous plants. The shrubs must occupy at least one-third of the site or the A or L fuel models should be used. Fuel Model T might be used for immature scrub oak and desert shrub associations in the West, and the scrub oak-wire grass type in the Southeast.

FUEL MODEL U

Closed stands of western long-needled pines are covered by this model. The ground fuels are primarily litter and small branchwood. Grass and shrubs are precluded by the dense canopy but occur in the occasional natural opening. Fuel Model U should be used for ponderosa, Jeffrey, sugar pine, and red pine stands of the Lake States. Fuel Model P is the corresponding model for southern pine plantations.

APPENDIX C

SELECTION OF SLOPE CLASS

In the 1972 NFDRS, three slope classes were used: 0-20 percent, 21-40 percent, and greater than 40 percent. This was not sufficient for mountainous areas where slopes to 100 percent are found.

The number of slope classes has been increased to five, with 90 percent the midpoint of the last class. The classes were selected so that the effect would double if the next higher slope class is used. In other words, slope class 5 will have 16 times (2^4) the effect as slope class 1.

The basic consideration for selecting the slope class is the topography in the base area where initial attack is commonly made. Once again, knowledge of the fire history of the protection unit is essential.

Slope class	*Slope (percent)*
1	0-25
2	26-40
3	41-55
4	56-75
5	greater than 75

APPENDIX D

LIGHTNING RISK

The assessment of lightning risk (LR) requires two inputs: the lightning risk scaling factor and the lightning activity level (LAL).

The *lightning risk scaling factor* is a multiplier that localizes the prediction of the basic lightning-caused fire occurrence model. It accounts for local storm and site characteristics not addressed by the prediction model. Guideline A contains the instructions for deriving the lightning risk scaling factor for a fire-danger rating area.

The *lightning activity level* (LAL) is a numerical rating from 1 to 6 keyed to the observed or forecasted state of thunderstorms and lightning in a rating area (guideline B).

The daily evaluation of LR is done in two steps:

1. Select the LAL that best represents the lightning and thunderstorm situation (forecasted) observed on each fire-danger rating area (forecast area) during the calendar day.

2. Calculate the LR. It will automatically be calculated if AFFIRMS is used. For those not using AFFIRMS, the directions and nomogram for figuring the LR manually are in *Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System* (Burgan and others 1977).

Guideline A: The Lightning Risk Scaling Factor.--The LR scaling factor is derived from local records of thunderstorm and lightning-caused fire occurrence records. It can be calculated with and without historical data on LAL's. Data on LAL's are only available since 1972. With data on LAL's the LR scaling factor is calculated as follows:

$$\text{LR scaling factor} = \frac{10 \times \Sigma \text{ FIRES}}{1.6 \times \Sigma \text{ LOI}}$$

where: Σ FIRES is the total number of lightning-caused fires occurring *within a 28-mile radius* of the station during the period of record.

Σ LOI is the total of the daily LOI's during the period of record. (This is available by years from FIRDAT (Furman and Helfman 1973; Furman and Brink 1976)).

EXAMPLE 1.--Forty-one lightning fires occurred within a 28-mile radius of the Hashknife Lookout in Arizona from 1974 through 1976. The yearly occurrence totals and the total of the LOI obtained from an FIRDAT run *using an initial LR scaling factor of 1.0* are summarized in the following tabulation.

Year	*Number of lightning fires*	*LOI total*
1974	12	214
1975	16	306
1976	13	272
	41	792

Calculating the LR scaling factor:

$$\text{LR scaling factor} = \frac{10 \times 41}{1.6 \times 792}$$

$$= 0.32$$

The second method of calculating the LR scaling factor is not as accurate as the first, but it will serve where there are no LAL data. Initially, records from adjacent forests, districts, or counties that have comparable fuel types and similar levels of lightning fire incidence should be consolidated. The resulting LR scaling factor can then be used for all of the units.

$$\text{LR scaling factor} = \frac{1}{0.75}\left[\frac{\Sigma\ \text{FIRES}}{A \times \Sigma\ \text{TSTM DAYS}}\right]$$

where: Σ FIRES is the total number of lightning-caused fires occurring on the area during the period of record.

Σ TSTM DAYS is the total number of days with reported thunderstorms during the period of record.

A is the size of the area in millions of acres.

0.75 is the number of lightning fires per million acres per thunderstorm day for the area used to develop the basic prediction model.

EXAMPLE 2.--The lightning fire and thunderstorm data for a National Forest in eastern Montana are summarized in the following tabulation. The forest area is 1.715 million acres.

Number of years	*Total number of lightning fires*	*Total number of thunderstorm days*
5	32	34

Calculating the LR scaling factor:

$$\text{LR scaling factor} = \frac{1}{0.75}\left[\frac{32}{1.715 \times 34}\right]$$

$$= 0.73$$

The LR scaling factor should be adjusted every 2 years to bring the model predictions in line with experience. If the LOI is properly derived, 0.1 fires per million acres should have occurred on the average per unit of LOI.

The adjustment to the LR scaling factor would be made as follows. Use at least 2 years of data for this computation:

$$\text{LR scaling factor (new)} = \text{LR scaling factor (old)} \times \left[\frac{10 \times \Sigma\ \text{FIRES}}{A \times \Sigma\ \text{LOI}}\right]$$

EXAMPLE 3.--The fire manager of the forest of example 2 wants to adjust the LR scaling factor for one planning zone. This particular zone is in the higher elevations of the forest where the fuel is primarily spruce and lodgepole pine. It covers 670,000 acres (0.67 million acres). The LOI's for the years 1976 and 1977 total 1,776; there were 191 fires. The old LR scaling factor as computed in example 2 is 0.73.

$$\text{LR scaling factor (new)} = 0.73 \times \left[\frac{10 \times 191}{0.67 \times 1{,}776}\right]$$

$$= 0.73 \times 1.61$$

$$= 1.17$$

Guideline B: The Lightning Activity Level.--The LAL forecasted for the current day is used to estimate the expected number of *new* fires in the rating area. The estimate of holdover or sleeper fires to be dealt with today is based on the LOI calculated for yesterday. The LAL used in yesterday's calculation must have been verified and, if necessary, the LOI corrected before being used. This is the responsibility of the fire weather observer.

Choosing the correct LAL is a difficult task. We have approached the problem from the perspective of the fire weather forecaster separately from that of the fire weather observer.

The Fire Weather Forecast

Forecast areas vary greatly in size but are seldom smaller than 2,500 square miles (1.6 million acres). Forecast areas will normally include all or portions of the fire-danger rating areas as delinated by the protection agency. Hence the predicted LAL for a forecast area may be used on several rating areas.

The predicted LAL should reflect the maximum level of activity expected in a forecast area. A prediction of average LAL would be no more valuable to the fire manager than a prediction of average temperature is to a citrus grower. For verification purposes a single observation of the predicted LAL should justify scoring the forecast as a "hit." If no observations of that LAL were made or if a higher LAL was reported, the forecast should be scored a "miss."

The Lightning Activity Level Guide for National Weather Service fire weather forecasters, table 7, contains information different from that provided to the protection organization's fire weather observers.

Table 7.--*Lightning activity level guide for fire weather forecasters*

LAL	Maximum radar echo height	Radar echos of indicated strength: Very light	Light	Moderate	Strong
	1,000's of ft MSL	*Minimum area coverage in percent*			
1	No echos	--	--	--	--
2	<28	10	5	--	--
3	26-32	20	10	5	--
4	30-36	20	10	5	--
5	>36	30	20	10	5
6[1]	--	--	--	--	--

[1]To be used for red-flag warnings for potentially extreme fire activity.

LAL's 1 through 5 correspond, roughly, to the five categories of thunderstorm density used for aviation route forecasts: none, isolated, few, scattered, and numerous. Lightning activity level 6 was added to describe the rare but very significant event known as the "lightning bust." In such situations the storms are characterized by high bases (as high as 15,000 feet above sea level), no precipitation, and a low frequency of cloud-to-ground lightning discharges (similar to LAL 3). A high percentage of strikes start fires.

LAL 6 may never occur in your forecast area. It is unlikely to occur in the eastern United States or west of the Cascades-Sierra crest. Thunderstorm activity corresponding to LAL 6 is most commonly observed in the Inland Empire, the Great Basin, and the Northern Rocky Mountains.

LAL's 4 and 5 are typically associated with fronts and squall lines. LAL's 2 and 3 represent the more common summer airmass thunderstorm events.

It is no longer necessary for the fire weather forecaster to predict if storms will be wet or dry. That factor was included in the model storms for LAL's 2 through 5. The forecaster should consider precipitation duration separately from that of the thunderstorm occurrence forecast. His prediction of precipitation duration should reflect what is expected *at the fire weather station* during the 24 hours from one basic observation time to the next. This is meant to be consistent with the policy of the National Weather Service regarding precipitation forecasts for the general public.

The Fire Weather Observation

The *Lightning activity level guide for observers* (table 8) describes clouds, storm, and lightning frequency criteria for classifying lightning events. Because the objective is to describe the lightning activity, lightning counts take precedence over the cloud-storm-rain narrative descriptions.

For instance, if the clouds should fit the LAL 3 descriptive criteria, but the lightning averages three cloud-to-ground discharges per minute, the LAL should be classified as a 4.

Also included in the *Lightning activity level guide for observers* is the relative frequency of occurrence of the various LAL's. For instance, LAL 6 is a rare event not likely to occur on more than 1 or 2 percent of the lightning days.

The observation of lightning (the LAL) should include what has happened within a 25 to 30 mile radius of the station (1.6 million acres).

The fire weather observer must obtain as much information as possible from all available sources to insure an accurate LAL observation. The fire weather forecaster has other sources of information on thunderstorm activity, and therefore, should be consulted if there is confusion over the selection of an LAL.

Table 8.--*Lightning activity level guide for fire weather observers*

LAL	Cloud and storm development	Individual storm cell--cloud to ground lightning discharges: Counts [1]cg/5 min	Counts cg/15 min	Average (cg/min)	Percent of thunderstorm days
1	No thunderstorms	--	--	--	--
2	Cumulus clouds are common but only a few reach the towering cumulus stage. A single thunderstorm must be confirmed in the rating area. The clouds mostly produce virga but light rain will occasionally reach the ground. Lightning is very infrequent.	1-5	1-8	<1	10
3	Cumulus clouds are common. Swelling and towering cumulus covers less than two-tenths of the sky. Thunderstorms are few, but two to three must occur within the observation area. Light to moderate rain will reach the ground, and lightning is infrequent.	6-10	9-15	1-2	35
4	Swelling cumulus and towering cumulus cover 2-3/10 of the sky. Thunderstorms are scattered but more than three must occur within the observation area. Moderate rain is commonly produced, and lightning is frequent.	11-15	16-25	2-3	35
5	Towering cumulus and thunderstorms are numerous. They cover more than three-tenths and occasionally obscure the sky. Rain is moderate to heavy, and lightning is frequent and intense.	>15	>25	>3	18
6[2]					<2

[1]Cloud-to-ground lightning discharges.
[2]Used for red-flag warnings of potential extreme fire activity.

APPENDIX E

MAN-CAUSED RISK

The assessment of man-caused risk (MCR) requires three inputs. The first input is a number *called the MCR scaling factor,* which adjusts the prediction of the basic man-caused fire occurrence model to fit local experience.

The second, the *risk source ratios,* represents the contributions of each of the eight standard statistical causes (*risk sources*) listed on any fire report (USDA Form 5100-29 or USDI Form D1-1201) to the man-caused fire problem. The MCR scaling factor and risk source ratios are both derived from an analysis of the succeeding 3 to 5 years of fire and fire weather data.

The third input, the *daily activity levels,* is the fire manager's estimate of the status of each of the *risk sources.*

The daily evaluation of MCR is done in three steps:

1. Select the *daily activity level* appropriate for each *risk source.*

2. Using nomogram E-1, determine the *partial risk* for each *risk source* from its *daily activity level* and *risk source ratio.* Sum up the partial risks to obtain the *unnormalized man-caused risk.*

3. Enter nomogram E-2 with the *unnormalized man-caused risk* and the protection unit's *MCR scaling factor* to obtain the MCR.

This procedure must be used to determine the MCR for *both* computer and manual calculations of NFDRS ratings. Working copies of E-1 and E-2 are provided in the back of this book.

Keyed to the information flow diagram in figure 3 are guidelines A through E, which tell how to determine the inputs and calculate the MCR.

Guideline A: The MCR Scaling Factor.--The most recent 5 years of fire and fire weather records are needed to evaluate the MCR scaling factor (3 years are sufficient in high man-caused fire areas). The analysis should be redone every 2 years so that current trends can be accounted for. The procedure for calculating the MCR scaling factor is:

1. Determine the total number of MC fires that occurred on protected land during the most recent 5 years (Σ FIRES).
2. Total the number of days in each of the five fire seasons and add together (Σ DAYS).
3. Determine the average of the daily values of IC for each of the five seasons. Calculate an overall average ($\overline{IC}$), weighting the yearly averages by the number of days in the respective season.
4. Determine the area of land protected in millions of acres and multiply by Σ DAYS. This value is million acre-days (A-DAYS).

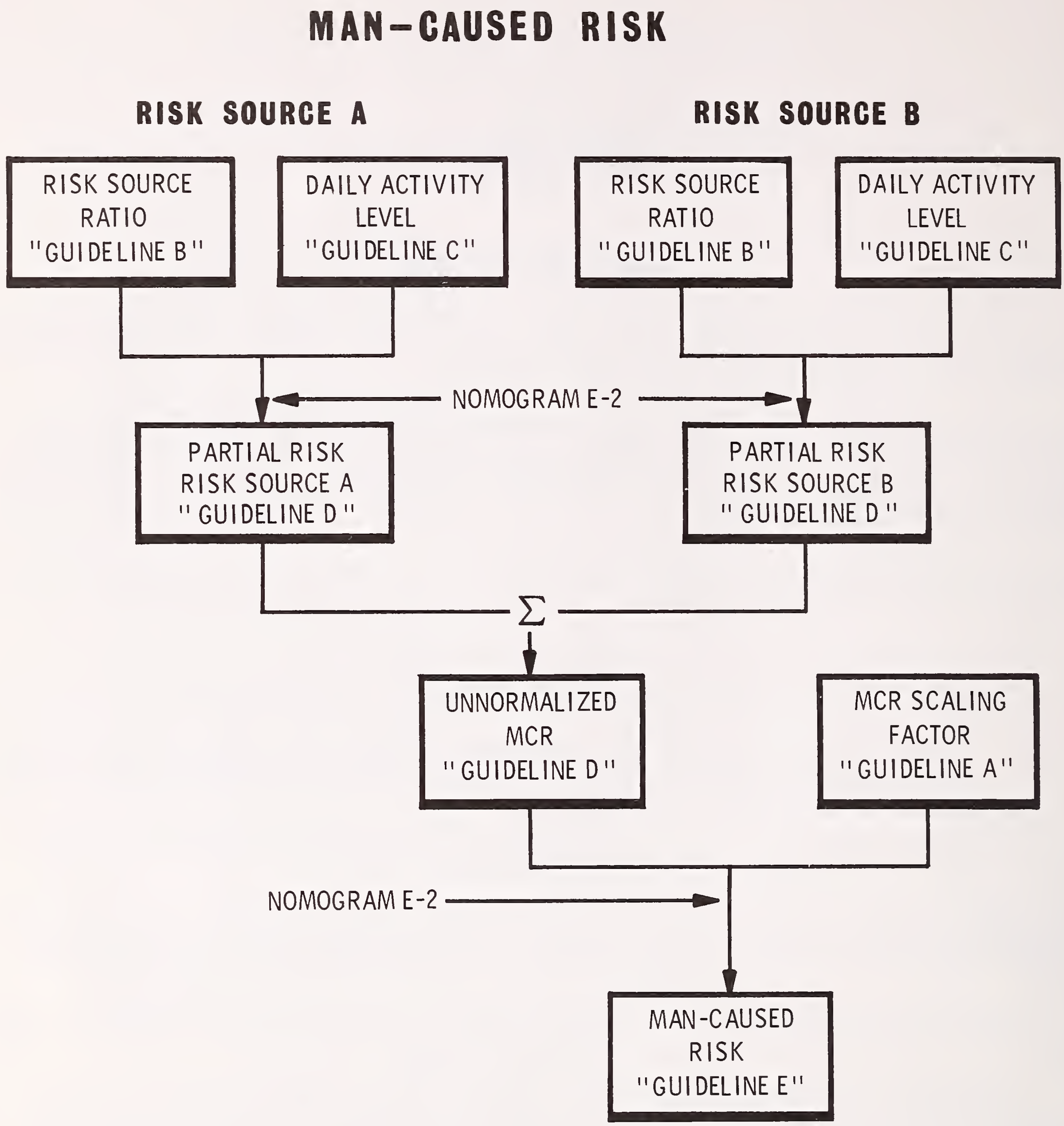


Figure 3.--Computation flow chart for determining man-caused risk. Only two risk sources, A and B, are shown. In reality, three to five risk sources are used and the partial risks summed to produce the unnormalized man-caused risk.

5. Calculate the MCR scaling factor according to the following formula:

$$\text{MCR scaling factor} = \frac{10 \times \Sigma\ \text{FIRES}}{\overline{\text{IC}} \times \text{A-DAYS}}$$

EXAMPLE.--The last five fire seasons in Pocossin County are summarized in the following tabulation.

a	*b*	*c*	*d*	*e*	*f*
Year	*No. of MC fires*	*Year's average IC*	*Fire season (days)*	*(c × d)*	$\overline{IC}$ *(Σe/Σd)*
1972	375	44.2	187	8,265	
1973	521	49.7	195	9,692	
1974	447	48.5	200	9,700	
1975	400	46.6	170	7,922	
1976	417	43.2	168	7,258	
	2,160		920	42,837	46.56 = 47

$\overline{\text{IC}}$ is the average of the yearly average IC's weighted by the number of days in the respective fire season. The weighting is done in columns e and f.

The third term in the equation is million acre-days (A-DAYS). It is the product of the protected area, in millions of acres, and the total number of days in the five fire seasons. The protected area in Pocossin County is 1.8 million acres.

$$\begin{aligned} \text{A-DAYS} &= \text{Area} \times \Sigma d \\ &= 1.8 \times 920 \\ &= 1{,}656 \end{aligned}$$

Calculating the MCR scaling factor:

$$\begin{aligned} \text{MCR scaling factor} &= \left[\frac{10 \times 2{,}160}{47 \times 1{,}656}\right] \\ &= 0.28 \end{aligned}$$

If several protection units have about the same fuels, weather, and fire problem, a single MCR scaling factor can be developed from the combined data of the units. This is desirable because the larger number of data will produce a more stable MCR scaling factor.

Guideline B: Evaluation of the Risk Source Ratios.--The relative contributions to fire starts of the several risk sources active on a protection unit may change with day of the week. For that reason, a risk source ratio is calculated for each risk source for each of the 7 days of the week.

It is not necessary, or desirable, to follow all eight statistical causes. The risk sources selected for monitoring should, at a minimum, have accounted for 70 percent of the man-caused fires during the past 3 to 5 years. In most cases, fewer than five risk sources will satisfy the 70 percent rule.

EXAMPLE.--74 percent of the man-caused fires occurring in the North Carolina County of Pocossin the past 5 years were attributable to incendiarism, debris burning, campfires, and machine use. The remainder of the causes are included in "all other."

Risk source	*No. of fires*	*Percent of fires*	
Incendiary	562	26	74%
Debris burning	475	22	
Campfires	194	9	
Equipment use	367	17	
All other	562	26	
Total	2,160	100	

By day of the week, the fires were distributed as follows:

Risk source	*Mon*	*Tues*	*Wed*	*Thur*	*Fri*	*Sat*	*Sun*	*Total*
			*Number of fires**					
Incendiary	9	26	60	72	80	80	72	399
Debris burning	29	37	43	60	143	264	100	677
Campfires	6	20	17	23	55	66	75	261
Equipment use	57	63	60	75	89	11	9	364
All other	49	63	80	52	57	89	69	459
5-YEAR TOTAL								2,160

*If less than five but more than zero fires occur, use 5.

The risk source ratio is calculated using this formula:

$$\text{Risk source ratio} = \frac{700 \times \text{No. of fires for day of week}}{\text{Total fires}}$$

For instance, the risk source ratio for debris burning for a Thursday would equal:

$$\frac{700 \times 60}{2{,}160} = 19$$

Using this formula, the array of risk source ratios by day of week for the five risk sources in the example looks like this:

Risk source	*Mon*	*Tues*	*Wed*	*Thurs*	*Fri*	*Sat*	*Sun*
			Risk source ratios				
Incendiary	3	8	19	23	26	26	23
Debris burning	9	12	14	19	46	86	32
Campfires	2	6	6	7	18	21	24
Equipment use	18	20	19	24	29	4	3
All others	16	20	26	17	18	29	22

Guideline C: Evaluation of the Daily Activity Level.--Unlike the risk source ratios and the MCR normalizing factor, which are semipermanent, objectively derived numbers, the daily activity levels must be evaluated each day. Because they are subjectively determined, the fire manager must monitor factors that might cause deviations in the status of the selected risk sources *from what is normal for that particular day of the week.*

Deviations from NORMAL are rare. NONE or EXTREME *might* occur only 10 percent of the time; LOW or HIGH, 20 percent of the time. The daily activity level guide is as follows:

DAL	*Relative value*	*Percentage of occurrence*	*Description*
NONE	0	5	Risk source totally inactive.
LOW	1	10	Risk source activity well below normal for the day of the week.
NORMAL	2	70	Activity typical for the day of the week.
HIGH	4	10	Risk source unusually active; about twice the typical level for the day.
EXTREME	8	5	Activity of the risk source unusually high. Appropriate only for risk sources that are highly variable such as incendiary.

Remember this very important principle: *The assessment is relative to what is normal for that day of a typical week during the fire season.* This is a significant refinement of the 1972 NFDRS procedures, where the reference was much less precisely defined.

Recreation-related activities are heavily influenced by the weather--current and forecasted. Other risk sources such as railroads are very persistent and should be carried as NORMAL, except under very unusual circumstances.

Risk source ratios will automatically account for the weekend peaks of recreational activity, but what about the 3-day weekend or a holiday in the middle of the week? On such occasions, HIGH or even EXTREME daily activity levels may be warranted for the risk source that covers recreation-related causes.

Consider seasonal influences also. Debris burning is primarily a fall and spring activity. During these periods, a HIGH or EXTREME rating can easily be justified. Some recreational pursuits, such as hunting, are also very seasonal.

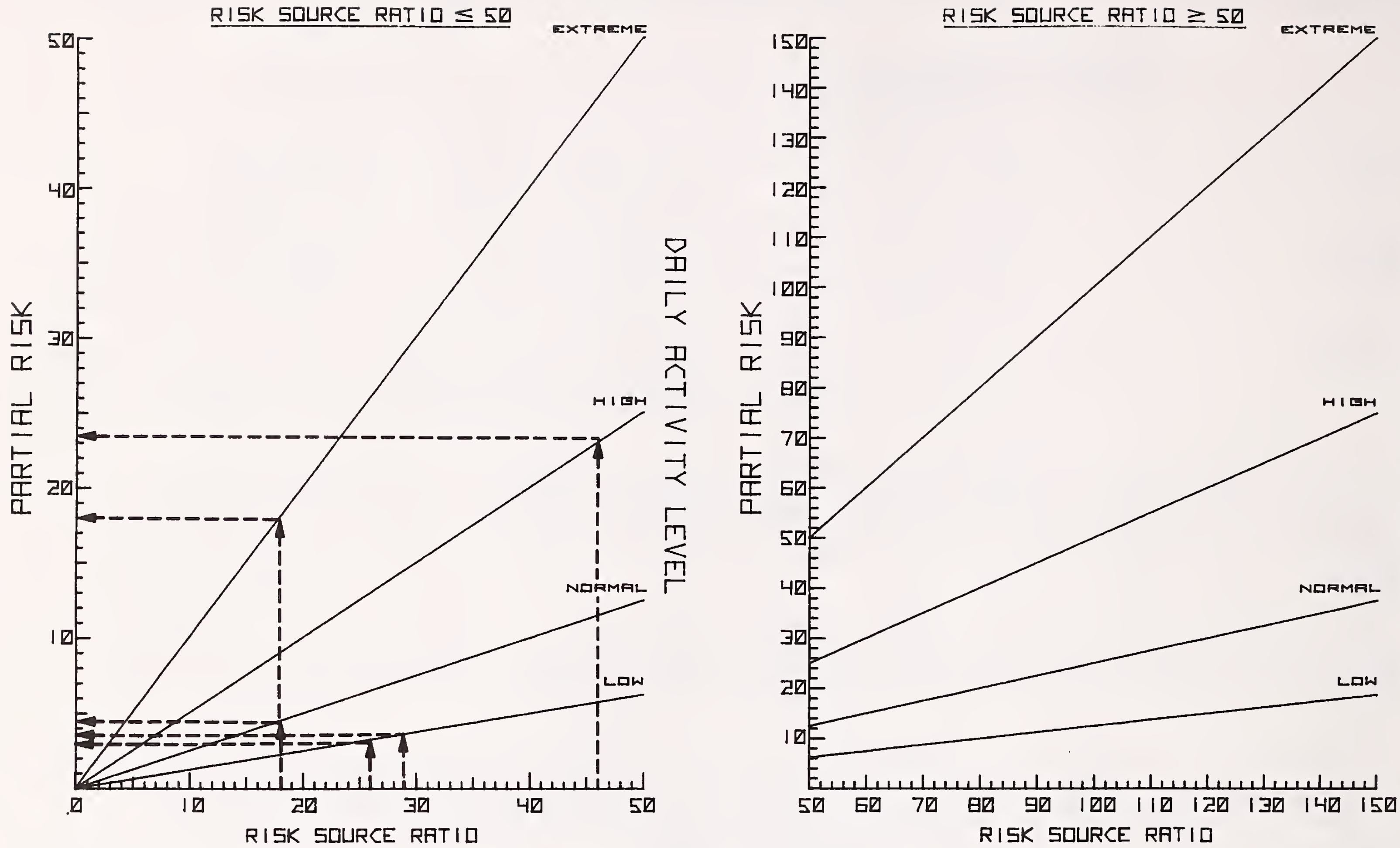
Guideline D: Calculation of the Unnormalized Man-Caused Risk.--The partial risk contributed by each risk source is obtained from nomogram E-1. The inputs are the daily activity level and the risk source ratio of the particular risk source. The unnormalized man-caused risk is the *sum* of the partial risks contributed by each of the risk sources.

EXAMPLE: November 2 is Founder's Day, a holiday that falls on Friday. Nomogram E-1 is used to calculate the partial risks. The unnormalized man-caused risk is the sum of the partial risks--in this case, 53.

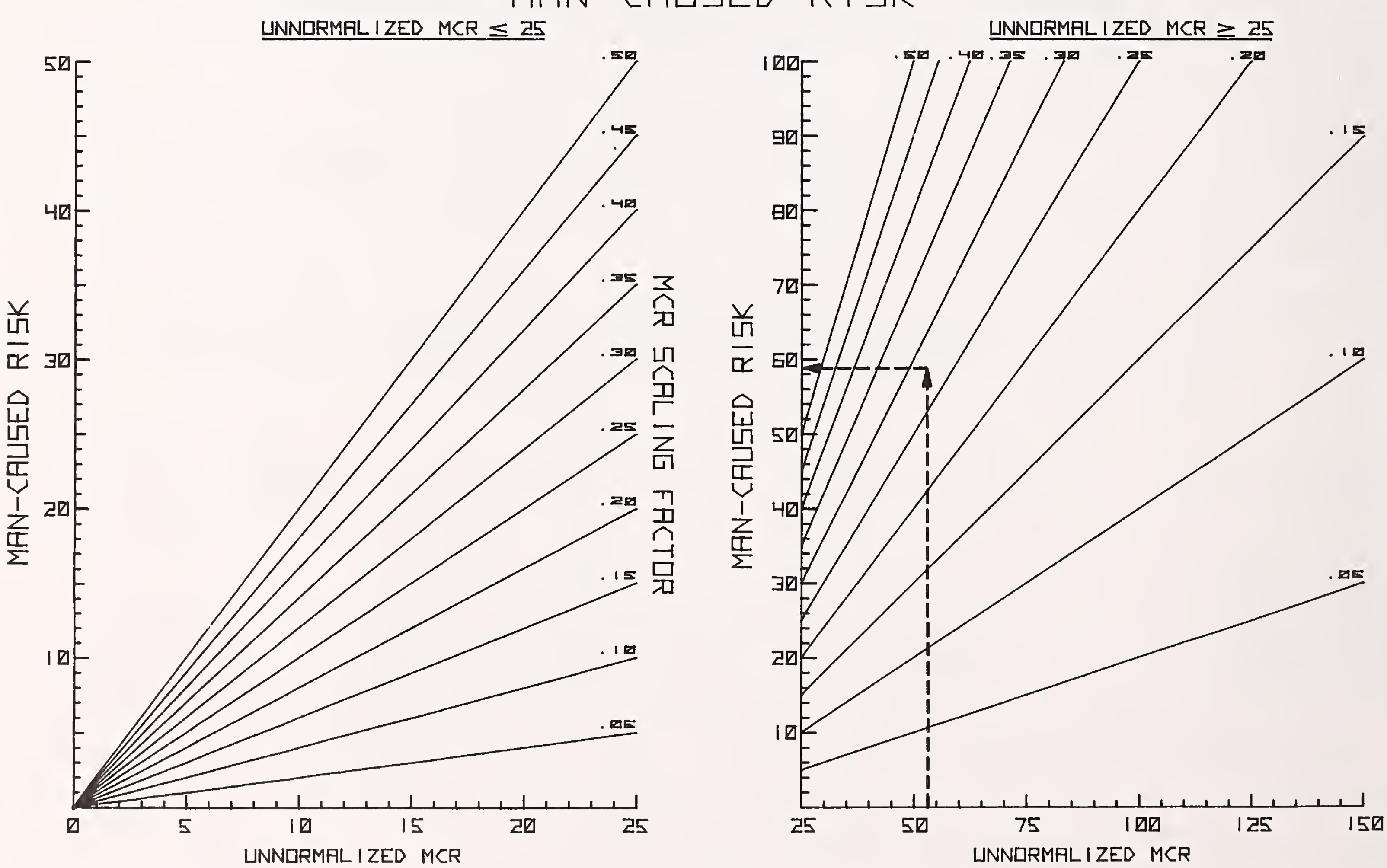
Risk source	*Risk source ratio*	*Daily activity level*	*Partial risk*
Incendiary	26	LOW	3
Debris burning	46	HIGH	23
Campfires	18	EXTREME	18
Machine use	29	LOW	4
All other	18	NORMAL*	5
UNNORMALIZED MAN-CAUSED RISK**			53

*The "all other" risk source is always assigned a daily activity level of NORMAL.
**The unnormalized MCR may total more than 100.

NOMOGRAM E-1
PARTIAL RISK



NOMOGRAM E-2
MAN-CAUSED RISK



Guideline E: Calculation of Man-Caused Risk.--The value of MCR entered into the computer or into column 18 of the 10-day fire danger and fire weather record, if you are calculating the NFDRS ratings manually, is determined with nomogram E-2. The unnormalized man-caused risk and the MCR scaling factor are the inputs.

EXAMPLE: Again consider Pocossin County; entering nomogram E-2 with an unnormalized man-caused risk of 53 and an MCR scaling factor of 0.28. The MCR is 58. MCR cannot exceed a value of 100

Figure 4 is a suggested form for computing man-caused risk that the user may find convenient to copy and reproduce.

MAN-CAUSED RISK COMPUTATION FORM

Unit____________________ Date__________

MCR scaling factor____________________ Day of week__________

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1.			
2.			
3.			
4.			
5.			

Total - Unnormalized MC RISK - - - - - - - - - - - - - __________

MCR (E-2) - - - - - - - - - - - - - - - - - - - __________

Figure 4.--Form for computing man-caused risk.

Working copies of nomograms E-1 and E-2 are provided in the back of this book.

APPENDIX F

INTERPRETATION OF THE OCCURRENCE INDEXES

The Lightning Fire Occurrence Index (LOI) and the Man-Caused Fire Occurrence Index (MCOI) can be interpreted in units of fire density, fires per million acres. At a value of 100, either index projects an average of 10 fires per million acres. Or put another way, each unit of index indicates an expectation of 0.1 fire per million acres.

You must be careful not to take the projections too literally on any given day. The indexes are meant to indicate what will happen *on the average* under similar conditions.

OI's are easily translated from fires per million acres to fires per rating area. Simply multiply the respective OI's by the area of the rating area in millions of acres and divide by 10.

EXAMPLE: Pocossin County has a protected area of 1.8 million acres. When the MCOI equals 66 and the LOI equals 5, on the average, a total of 13 fires should be expected in the county.

OI	*Area of rating unit (10^6 ac)*	*Index value*	*Expected number of fires*
MCOI	1.8	66	12.0
LOI	1.8	5	1.0
			13.0

In the preceding example, the protection unit consists of only one rating area. That is, the fuels and topography are reasonably uniform and only one fire weather station is operated. What if this county extends over a portion of the Coastal Plains and the Piedmont? In this case the unit should be divided into two rating areas, hopefully each with its own fire weather station.

EXAMPLE: Pocossin County is divided into two rating areas, Plains and Piedmont. The areas are 1.5 and 0.3 million acres; the MCOI's are 66 and 53; and the LOI's are 5 and 0. About 10 fires are projected for the day.

Rating area	*OI*	*Area of rating unit (10^6 ac)*	*Index value*	*Expected number of fires*
Piedmont	MCOI	0.3	66	2.0
	LOI	0.3	5	.2
		Subtotal		2.2 fires
Plains	MCOI	1.5	53	8.0
	LOI	1.5	0	0
		Subtotal		8.0 fires
		Total		10.2 or 10 fires

APPENDIX G

INTERPRETATION OF THE BURNING INDEX

The summary publication of the 1972 NFDRS postulated that the effort required to contain a fire was proportional to the length of flames at the fire's head. New information indicates that difficulty of containment is proportional not to the flame length, but to the fireline intensity, the rate of heat release per unit length of fireline (Byram 1959). Following this latter hypothesis, the magnitude of the containment job actually increases more than twice as fast as the BI.

Flame length was related to fireline intensity by Byram (1959). Because the BI is based on flame length, the BI, fireline intensity, and flame length are interrelated.

Roussopoulos and Johnson (1975) compiled observations of Canadian, Australian, and American fire researchers relating fireline intensity to fire controllability and behavior. That information and the flame length and BI's corresponding to the critical fireline intensities are summarized in table 9.

It should be noted that the 1978 BI has been scaled to equal 78 when the predicted flame length is 7.8 feet. That flame length corresponds to a fireline intensity of 500 Btu/sec/ft. Above a fireline intensity of 500 Btu/sec/ft, it is unlikely that a fire can be controlled by conventional means. (Chemical retardants can possibly reduce the intensity of a fire below the 500 Btu/sec/ft level making direct attack feasible.)

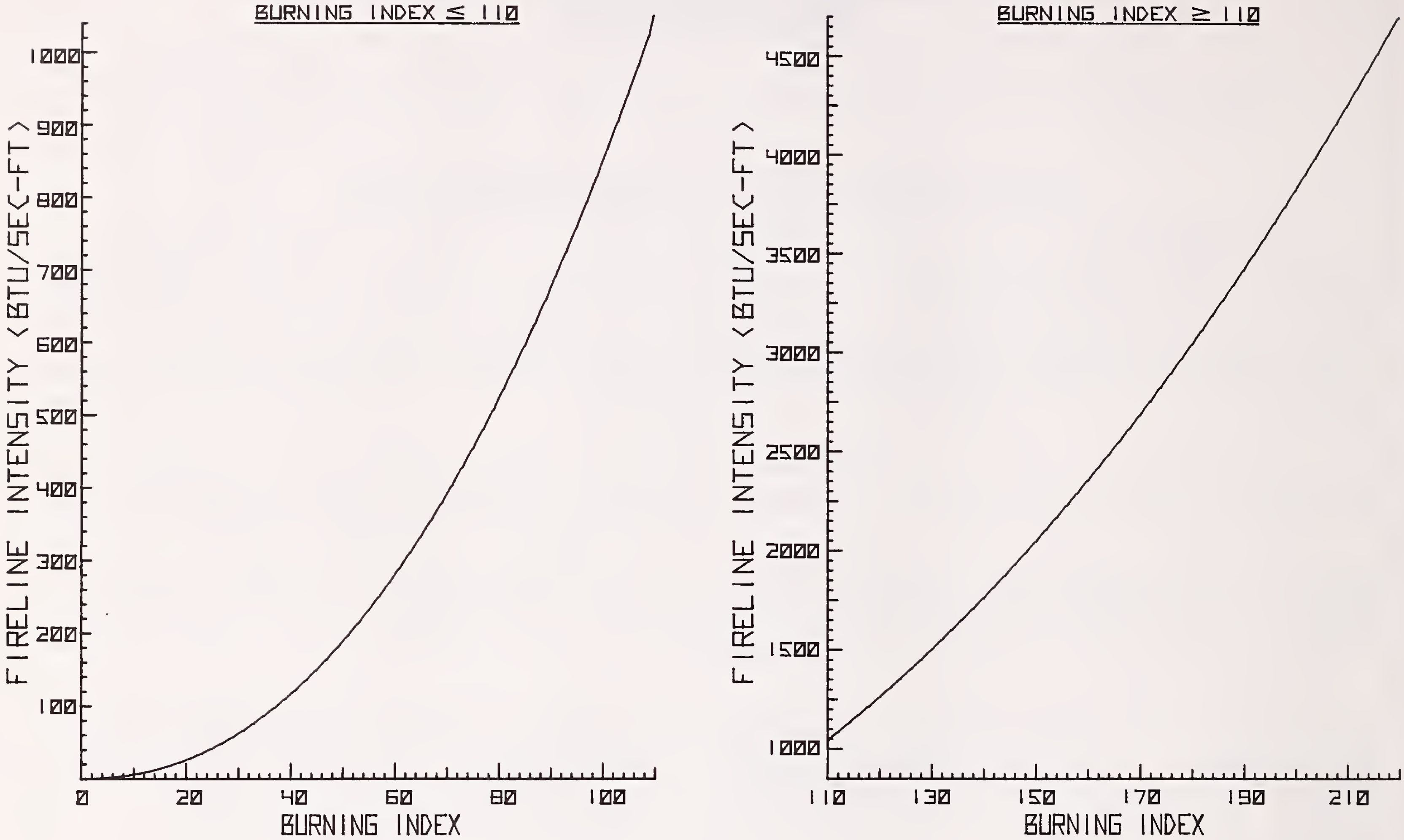
In nomogram G-1 the BI is plotted against fireline intensity. It can be used to derive *ideal* fireline intensity values from intermediate values of the BI.

Table 9.--*Fire behavior, controllability, and fireline intensity*

Burning index	Fireline intensity	Flame length	Narrative
	Btu/s/ft	*Ft*	
0-28	0-50	2.8	Most prescribed burns are conducted in this range
38	100	3.8	Generally represents the limit of control for manual attack methods.
78	500	7.8	The prospects for control by any means are poor above this intensity.
96	700	9.6	The heat load on people within 30 feet of the fire is dangerous.
108	1,000	10.8	Above this intensity, spotting, fire whirls, and crowning should be expected.

NOMOGRAM G-1

FIRELINE INTENSITY V/S BURNING INDEX



APPENDIX H

USING THE LIVE FUEL MOISTURE PREDICTION MODELS

Whether you are using AFFIRMS or calculating the fire-danger ratings manually, several procedures are common to both methods. The specifics for using AFFIRMS will be covered in a supplement to the AFFIRMS users' manual (Helfman and others 1975). Manual calculations will be covered in *Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System* (Burgan and others 1977).

Two tasks must be completed prior to using the 1978 NFDRS:

1. Herbaceous fuels in each fire-danger rating area must be designated as annuals or perennials.

2. A climate class must be specified for each rating area.

During the fire season, the fire manager must monitor the condition of live fuels and signal the live fuel moisture prediction model when certain events occur. Those key events are: (1) greenup, whether it is the initial flush of growth in the spring or whether it occurs in midseason because of unusually high precipitation or some other cause; and (2) curing due to physiological processes or as a result of freezing.

Guideline A: Selecting the Annual or Perennial Designation for Herbaceous Fuels.--The live fuel moisture model predicts faster drying and curing rates for annual species than for perennials.

If more than half the herbaceous plants in a rating area are annuals, designate them as annuals. Otherwise, they are perennials. Seldom will the annual class be appropriate in mountainous areas or east of the 100th Meridian.

Fuel Model A *must* be given an annual designation and Fuel Model L *must* be given a perennial designation.

Guideline B: Selecting a Climate Class.--The four NFDRS climate classes correspond to the humidity provinces of Thornthwaite's first climate classification system (Thornthwaite 1931). In adapting his system, we grouped the arid provinces with the semiarid provinces in climate class 1 because the true desert is of little real concern to fire management. Also, in terms of fire behavior, the subhumid province with adequate year-long precipitation groups better with the humid province than with the dry, subhumid province. Table 10 summarizes the characteristics of the climate classes and figure 5 shows their general distributions.

Table 10.--*Climate class selection guide.*

NFDRS climate class	Thornthwaite[1] humidity province	Characteristic vegetation	Regions
1	Arid	Desert (sparse grass and scattered shrubs)	Sonoran deserts of west Texas, New Mexico, southwest Arizona, southern Nevada, and western Utah; and the Mojave Desert of California.
1	Semiarid	Steppe (short grass and shrubs)	The short grass prairies of the Great Plains; the sagebrush steppes and pinyon/juniper woodlands of Wyoming, Montana, Idaho, Colorado, Utah, Arizona, Washington, and Oregon; and the grass steppes of the central valley of California.
2	Subhumid (rainfall deficient in summer	Savanna (grasslands, dense brush and open conifer forests)	The Alaskan interior; the chaparral of Colorado, Arizona, New Mexico, the Sierra Nevada foothills, and southern California; oak woodland of California; ponderosa pine woodlands of the West; and mountain valleys (or parks) of the Northern and Central Rockies.
3	Subhumid (rainfall adequate in all seasons)	Savanna (grasslands and open hardwood forests)	Blue stem prairies and blue stem-oak-hickory savanna of Iowa, Missouri, and Illinois.
3	Humid	Forests	Almost the entire eastern United States; and those higher elevations in the West that support dense forests.
4	Wet	Rain forest (redwoods, and spruce-cedar-hemlock)	Coast of northern California, Oregon, Washington, and southeast Alaska.

[1]Thornthwaite 1931.

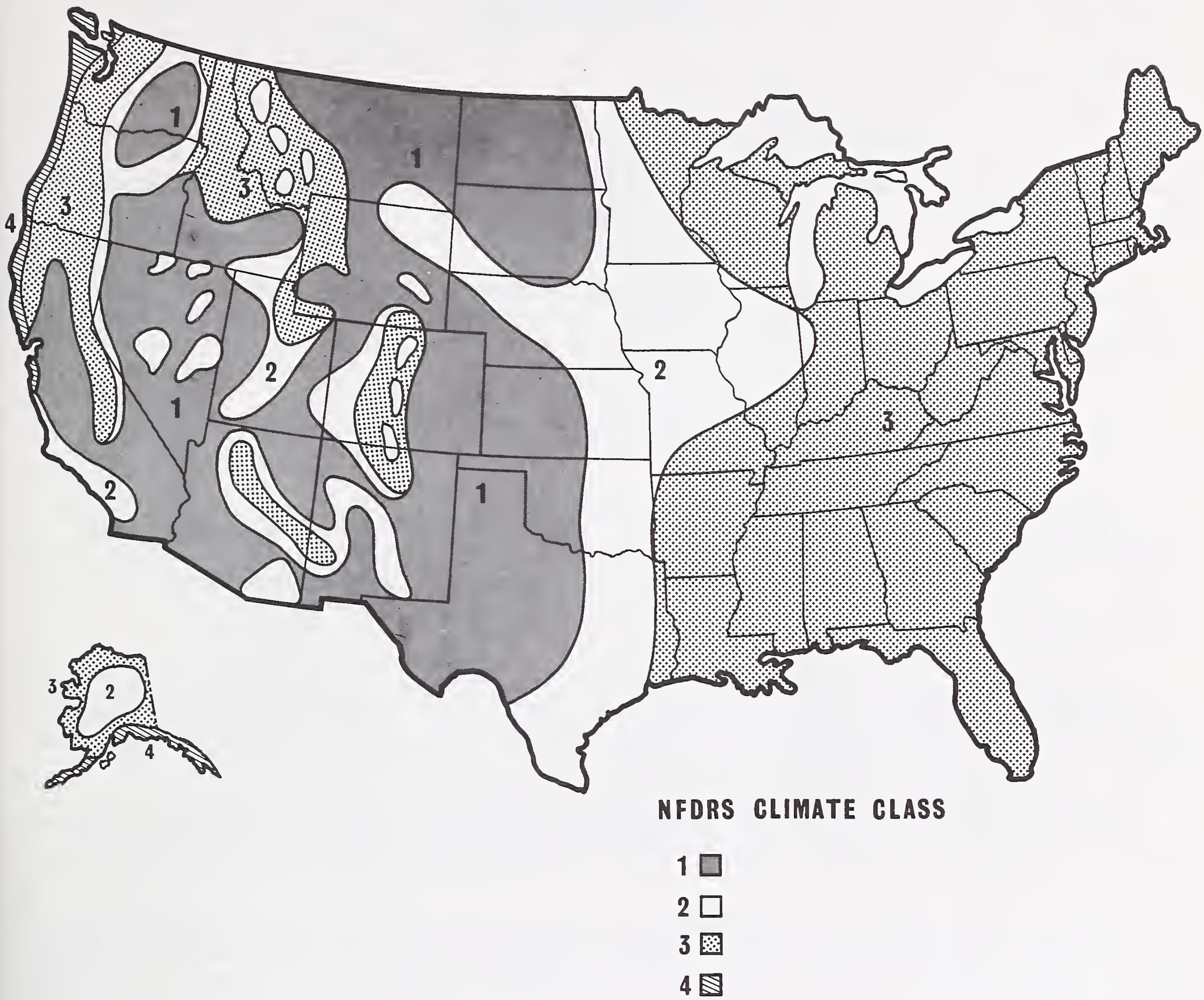


Figure 5.--Map of the United States showing the general locations of the NFDRS climate classes. The descriptions of the NFDRS climate classes, the geographical areas where they should be used, and the characteristic vegetation of those areas are tabulated in table 10.

The rules for selecting a climate class are flexible. The objective is to select the climate class that produces the best assessment of live fuel moisture conditions in the rating area. For instance, in the same geographical region a climate class for an area at high elevation will likely be different than the one used for rating areas at lower elevations.

There is nothing to prevent you from changing climate classes in the middle of the season. If the System is drying the live fuels too rapidly, go to the next lower climate class, namely, 2 instead of 3. Conversely, if the System is not drying the live fuels rapidly enough, use the next higher climate class, namely, 4 instead of 3.

However, you should be able to make a reasonable choice before hand by making FIRDAT runs (Furman and Helfman 1973; Furman and Brink 1976) for key stations using several climate classes. Choose the one that produces the best fit between the predicted and the observed live fuel conditions.

Selecting the climate class requires judgment and knowledge of the areas being rated. Climate class enables the user to *tune* the NFDRS to his area.

Guideline C: Greenup.--In all but the tropical areas of the United States, greenup will occur rather suddenly in the spring with warming temperatures. Greenup is signaled by the emergence of new growth on shrubs and trees, and the sprouting of herbaceous plants. In desert areas, or where the herbaceous ground cover consists primarily of annuals, rainy periods often cause a flush of new growth in the middle of the growing season.

In the interactive, time share computer program AFFIRMS, greenup is phased in over a period dependent on the climate class of the station. The time allowed for complete greenup is 7, 14, 21, and 28 days for climate classes 1, 2, 3, and 4, respectively. Hence, AFFIRMs users should declare greenup at the earliest appropriate time.

For those calculating the ratings manually, the greenup phasing feature is not available. In such cases, the user must not declare greenup until new growth is widespread. Otherwise, a premature reduction in the fire-danger ratings may result.

Guideline D: Curing.--Curing of the herbaceous fuels can come about in two ways: physiologically or due to freezing. Annuals normally complete their life cycle--sprout, flower, and produce seed--well within the normal growing season.

Perennial species usually cure very late in the season when temperatures drop below what is necessary for growth. Also, several days of below freezing temperatures or a single hard freeze may bring about a sudden end to growth in perennial herbs and forbs and in woody shrubs.

It is very important that you indicate when a cured condition exists. If the model has not already cured the herbaceous plants out, your signal will cause it to do so. As when declaring greenup, be careful to indicate curing only when the process is nearly complete. The fire-danger ratings may show a sudden increase when curing is declared, particularly for those fuel models having a high proportion of live woody material.

Guideline E: Coding Greenup and Curing.--In both the manual and computerized systems, spring or midseason greenups are indicated by a G for the herbaceous vegetation condition on *the day it occurs*. Curing without a freeze will be indicated by a C and curing by a freeze an F. In AFFIRMS the change in herbaceous vegetation condition is entered into the station catalog. In the manual system it will be entered in column 9 of the 10-day Fire Danger and Fire Weather Record.

APPENDIX I

THE 10-HOUR TIMELAG FUEL MOISTURE

The 10-h TL FM can be estimated using either of two methods:

1. From the weighing of the standard array of 1/2-inch ponderosa pine fuel sticks.

2. From mathematical models that require temperature, relative humidity, precipitation, and insolation data.

If the user chooses not to weigh fuel sticks and is subscribing to the AFFIRMS program, the 10-h TL FM will be automatically computed by the predictive model developed by NFDRS research. If the user is computing fire danger manually, the procedure for estimating the 10-h TL FM is covered by Burgan (Burgan and others 1977, appendix B).

The first option is preferred and recommended. Fuel sticks integrate the whole of the environment, including the effects of varying day length and cloudiness, better than any conceivable computational scheme.

In the 1972 NFDRS, the fuel stick moisture values were used directly as the 10-h TL FM. However, a number of workers (Nelson 1956; Morris 1959; Haines and Frost[3]) have shown that weathering significantly reduces the dry weight of fuel moisture sticks. If that weight loss is not taken into account, the reported moisture contents will be lower than actual; the result is an inflated fire-danger rating.

The nomogram I-1 is to be used for estimating the 10-h TL FM from the fuel stick weight. Nomogram I-1 is taken from the recent study by Haines and Frost.[3] A working copy of I-1 is provided in the back of this book.

To use the nomogram, locate the value corresponding to the observed fuel stick moisture content on the x-axis (horizontal). Trace upward parallel to the y-axis until you intercept the diagonal line corresponding to the age of the fuel sticks (interpolate when required). The 10-h TL FM is read from the y-axis directly to the left of the intersection point.

EXAMPLE.--If the observed fuel stick moisture is 11.5 grams and the sticks have been used for 2 months, what is the correct 10-h TL FM?

Answer.--14.5 percent.

Clean and balance your scales frequently. Inspect the fuel sticks daily for rodent chewing and checking, and replace if any damage is discovered. A replacement set of sticks should be set out a minimum of 1 week before being used to rate fire danger.

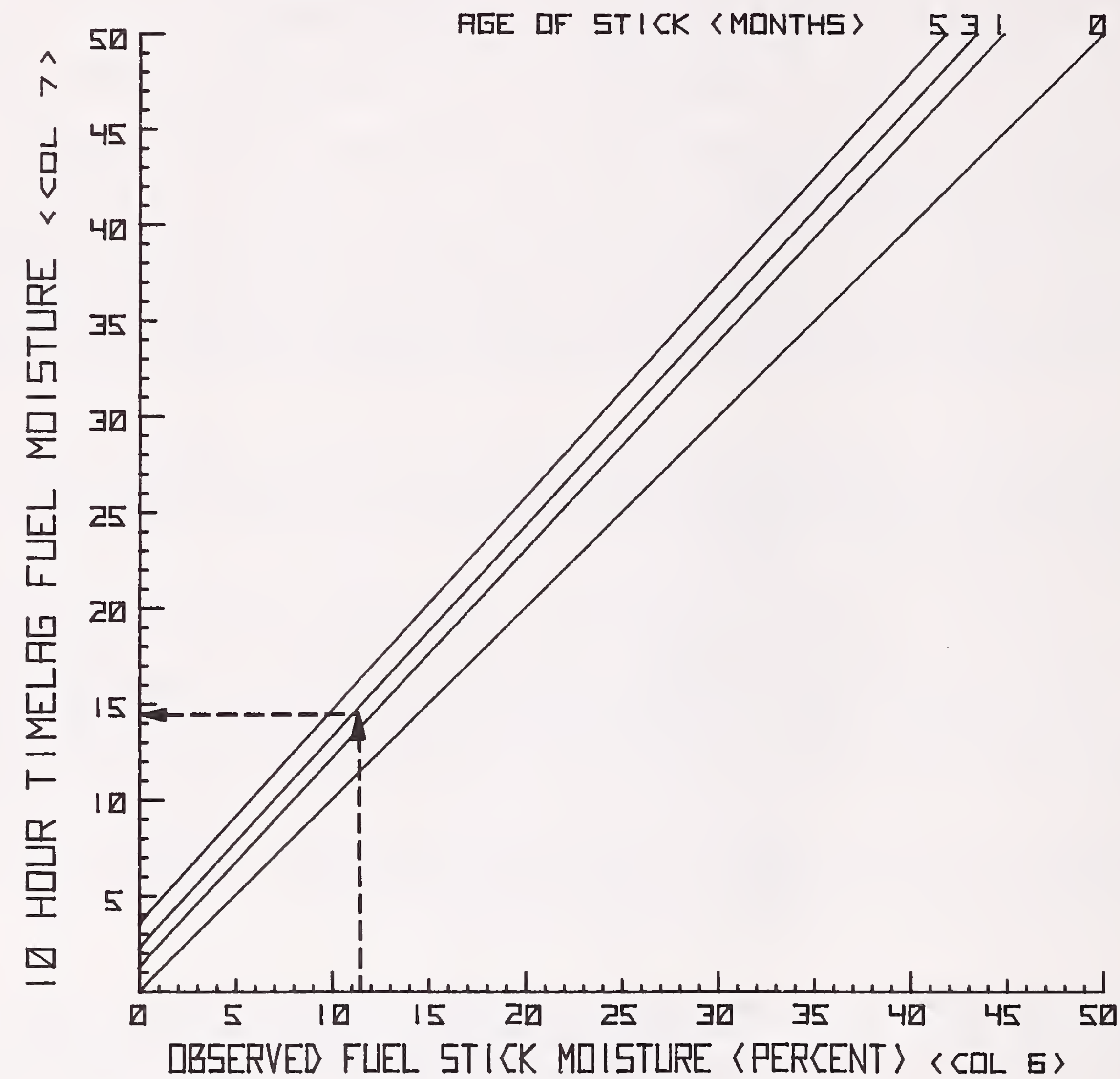
Fuel sticks should be supported on a wire rack 10 inches above a conifer or hardwood leaf litter, sawdust, or wood chip covered surface. They should be located so as to be in full sun from at least 0900 to 1500 local time.

---

[3]Haines, Donald A., and John S. Frost. Weathering of 100-g (1/2-inch) fuel moisture sticks. USDA For. Serv. Res. Note, North Cent. For. Exp. Stn., St. Paul, Minn. (in preparation).

NOMOGRAM I-1

10 HOUR TIMELAG FUEL MOISTURE



APPENDIX J

THE 10-DAY FIRE DANGER AND FIRE WEATHER RECORD

This form (fig. 6) and the instructions for its use that follow have been proposed to the National Weather Service to replace the WS Form D-9a. The new form has been designed to serve both as a worksheet for manually calculating the fire-danger ratings manually and as a weather recording form.

10 DAY FIRE DANGER AND FIRE WEATHER RECORD	Agency		Unit			Station Name	Station Number
	Station Elevation	Fuel Model / Annual or Perennial	Slope Class	Climate Class	Basic Obs Time (LST)	Period of Record (Month,Day,Year) From	To

		Temperature								Burning Index: Wind						Occurrence Indexes					Observer / Checked By
Day of Month	State of Weather	Dry Bulb	Wet Bulb / Dew Point	Relative Humidity	Observed Fuel Sticks	10-Hr TL Fuel Moisture	1-Hr TL Fuel Moisture	Herb. Veg. Condition	Fine Fuel Moisture	Direc-tion	Speed	Spread Component	Energy Release Component		Ignition Component	Lightning Risk	Lightning Occurrence Index	Man-caused Risk	Man-caused Occurrence Index	Fire Load Index	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
0																					
31																					

	Daily (24 Hour) Data: Temperature		Relative Humidities			Precipitation					Lightning				1000-Hr TL Fuel Moisture				Living Fuel Moistures						
Day of Month	Maximum	Minimum	Maximum	Minimum	Average	Kind	Began	Ended	Duration	Amount	Began	Ended	Activity Level	100-Hr TL Fuel Moisture	Today s 1000-Hr Bndry Value	Average 7 Day Bndry Value	Change 1000-Hr Fuel Moisutre	1000-Hr TL Fuel Moisture	Woody Fuel Moisture	X1000 Moisture Value	Herb Fuel Moisture				
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	A	B	C	D
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
0																									
31																									

Figure 6.--National Weather Service 10-Day fire danger and fire weather record. This form was designed for manual computation of the NFDRS. Its format follows the standardized sequence outlined by Burgan (Burgan and others 1977).

WS Form ____
Prec. by WCOM D-9a

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service

GENERAL INSTRUCTIONS

The WS Form ____ is designed to give uniformity to recordings of fire weather and fire-danger rating data. Objectives are:

1. To provide a means for recording weather and fuel data necessary for calculation of fire-danger rating values.

2. To facilitate computation of the fire-danger rating values.

3. To provide for the recording of selected climatological information.

The time of BASIC observation will be established by fire managers in consultation with the National Weather Service fire weather forecaster. Once the BASIC observation time is established, it should not be changed; for example, if the BASIC observation is established at 1300 local standard time (LST), then it should be taken at 1400 whenever daylight savings time (DST) is observed.

The WS Form ____ will be completed in duplicate; however, more or fewer copies may be required by your agency. Use fresh carbon paper and a hard pencil (2-3/4, 3, or 2H) with a sharp but rounded point. Please DO NOT use a ballpoint pen or typewriter. Entries must be neat and legible. On the 1st, 11th, and 21st days of each month, dispose of the forms for the preceding 10 days as your agency directs.

Questions concerning instructions, observations, or use of this form should be addressed to your fire weather forecaster.

RECORDING READINGS FROM INSTRUMENTS: ROUNDING OF ENTRIES--In reading thermometers and other instruments, values will seldom fall exactly on a graduation. If the value is halfway, or more than halfway, between two graduations, record the next highest value; if less than halfway, record the lower value. Example:

Thermometer reads 82.5°	Record 83
Rain measures 0.055 inch	Record 0.06
10 min average wind is 2.5 mi/h	Record 3
Fuel stick moisture content is 12.4%	Record 12
Average relative humidity is 42.5%	Record 43

STARTING THE WS FORM ____--Fill in all heading spaces to identify and locate your station; the name of your forest, district (BLM), county, etc., should be entered under "Unit." The "Station Number" will be provided by the fire weather forecaster. The "Fuel Model," "Slope Class," "Annual-Perennial," and "Climate Class" applicable to the rating area will be supplied by your local fire management officer. Using the 24-hour clock, enter the "Basic Observation Time" in local standard time (LST) EVEN WHEN DAYLIGHT SAVINGS TIME IS BEING OBSERVED.

This form is a 10-day record to cover the period(s) 1-10, 11-20, and 21-end of month. Make the appropriate "Period of Record" entry. NEVER ENTER DATA FROM MORE THAN ONE OF THESE PERIODS ON THE SAME SHEET. LEAVE BLANK THOSE LINES FOR DAYS WHEN OBSERVATIONS ARE NOT TAKEN.

At the beginning of the season, an initial value of 30 percent can be assumed for the 100-hour timelag fuel moisture (col. 36) and the 1,000-hour timelag fuel moisture (col. 40). Other starting values can be used if there is evidence that these values are inappropriate.

Column number	COLUMN INSTRUCTIONS
1	*Day of the Month.* In the first 10 days of the month (first decade) change the zero to 10. In the second decade, insert figures so days will read 11 to 20, and in the third decade, 21 to 30. Line 31 is used only in months having 31 days.
2	*State of Weather.* Record highest applicable code number describing the weather at BASIC observation time from the table below:

Code	*State of Weather*
0	Clear (less than 1/10 of sky cloud covered).
1	Scattered clouds (1/10 to 5/10 cloud covered).
2	Broken clouds (6/10 to 9/10 cloud covered).
3	Overcast (more than 9/10 of sky cloud covered).
4	Foggy.
5	Drizzling (precipitation of numerous fine droplets; in some areas referred to as "misting").
6	Raining.
7	Snowing or sleeting.
8	Showering (showers in sight or occurring at station).
9	Thunderstorm in progress (lightning seen or thunder heard). At lookout stations and others having unrestricted visibility, record thunderstorm in progress only when activity is not more than 30 miles away.

Column number	COLUMN INSTRUCTIONS
3 & 4	*Dry and Wet Bulb Temperatures.* Read thermometers to nearest whole degree. Use a minus sign to indicate temperatures below zero. If this form is being used to record forecasted weather information, the dew point can be recorded in col. 4 if needed.
5	*Relative Humidity.* Determine from National Weather Service psychrometric tables, series TA No. 454-0-1 (A, B, C, D, or E as appropriate for your elevation).
6	*Fuel Stick Weight.* Determine the weight of the 1/2-inch fuel moisture sticks to the nearest gram. If the sticks are snow or ice covered, or if it is raining at BASIC observation time, shake the snow, ice, or water from the sticks before weighing; enter 98 in col. 9.
7	*10-h Timelag Fuel Moisture.* Determine the fuel stick moisture content using the appropriate NFDR nomogram. If fuel sticks are not used, compute by the optional NFDR method.
8	*1-h Timelag Fuel Moisture.* Compute using the appropriate NFDR nomogram.
9	*Herbaceous Vegetation Condition.* This entry will be supplied by your local fire management officer in accordance with NFDR instructions. Code "G" for greenup; "C" for cured; and "F" if curing occurs due to a freeze.
10	*Fine Fuel Moisture.* Compute using the appropriate NFDR nomogram.
11	*Wind Direction.* Enter the direction FROM which wind is blowing. Make entry using following code: NE, 1; E, 2; SE, 3; SW, 5; W, 6; NW, 7; N, 8; Calm, 0.
12	*Windspeed.* Enter the 10-minute average speed to nearest whole mi/h.

Column number	COLUMN INSTRUCTIONS
13, 14, 15 & 16	*Spread Component, Energy Release Component, Burning Index, and Ignition Component.* Compute using the NFDR nomograms appropriate for your fuel model.
17 & 18	*Lightning Risk and Lightning Occurrence Index.* . Compute using the appropriate NFDR nomograms.
19	*Man-Caused Risk.* Compute in accordance with NFDR instructions.
20 & 21	*Man-Caused Occurrence Index and Fire Load Index.* Compute using the appropriate NFDR nomogram.

REMARKS.--Enter information such as "a second period of precipitation" or "thunderstorm event" and weather information that is not otherwise recorded, such as "rain changes to snow." Also, explain any data not clarified in a column entry, identifying data and column. For example: on the 9th at 1330, the wind shifted abruptly from SW at 15 mi/h to NW at 25 mi/h. Under remarks enter "col. 11--at 1330 wind shifted from SW 15 to NW 25." Note "fuels wet or snow (or ice) covered" when appropriate. Be sure entries begin on the line corresponding to the date of occurrence. Reasons for missing an observation should also be recorded. Make all entries as brief as possible.

DAILY (24-hour) DATA

Data in col. 23 through 26, 31, and 32 are for the period from BASIC observation time yesterday to BASIC observation time today. Entries in col. 29, 30, 33, 34, and 35 cover the period from 0001 to 2400 LST of the *date of occurrence.* (See example in col. 32 instructions.)

22	*Day of the Month.* See col. 1 instructions.
23 & 24	*Temperatures, Maximum and Minimum.** Record to the nearest whole degree. The maximum temperature (read today) cannot be lower than the dry-bulb temperature at observation time yesterday or today. The minimum temperature (read today) cannot be higher than the dry-bulb temperature at observation time yesterday or today.
25 & 26	*Humidity, Maximum and Minimum.*[1] If recording instruments are not available, estimate in accordance with the NFDR instructions.
27	*Average Relative Humidity.* Record to the nearest whole percent. Compute by adding the entries in col. 25 and 26 and dividing by two.
28	*Precipitation Kind.* Enter highest applicable code number as follows:

0	No precipitation	7	Snow or sleet
5	Drizzle	8	Showers
6	Rain	9	Hail

Note: If "zero" is entered in col. 28, leave col. 29, 30, 31, and 32 blank.

29 & 30	*Time Precipitation Began and Time Ended.** Use 24-hour clock, making entries to the nearest hour on the dateline of occurrence. Use "Remarks" space for indicating more than one period of precipitation. If beginnings and endings are unknown, estimate and note in "Remarks." Use the entry "cont" to denote precipitation continuing past midnight.

Column number	COLUMN INSTRUCTIONS

31 *Precipitation Duration.** This value should represent the total time that fuels were exposed to liquid water (rain) since BASIC observation time yesterday. If several periods of rainfall occurred, this value should be the cumulative total of the durations of all occurrences rounded to the next highest full hour. If it is raining at the time of BASIC observation, the duration of rainfall up to that time is recorded; the remainder of the storm will be accounted for the following day, *if, and only if the total duration of the storm for both days exceeds 1 hour.* Rains lasting less than one-half hour *and* producing only a trace amount should be disregarded. If more than a trace is received, a minimum of 1 hour should be entered in col. 31. Treat hail and snow as rain.

32 *24-hour Precipitation Amount.** Always empty the gage after taking a measurement. If no precipitation occurs, record a zero. If less than 0.005 inch occurs, record as a trace (T). 0.005 inch will be recorded as 0.01 inch. Melt snow and hail and measure the same as rain.

Example of recordings for a rainfall event:

	Rain begins	*Rain ends*	*Measured at BASIC time of 1300 LST*
July 2	8:30 a.m.	12:15 p.m.	0.15
July 2	3:00 p.m.	5:30 p.m.	
July 2	8:30 p.m.	cont.	
July 3	cont.	2:30 a.m.	0.45

Record these events as follows:

Date	Kind	Time began	Time ended	Duration	Amount	Remarks
2	6	08	12	4	0.15	Rain 15-18 and 21 cont.
3	6	cont.	03	9	0.45	

33 & 34 *Time Lightning Began and Time Ended.* Use 24-hour clock, making entries to the nearest hour on the dateline of occurrence. Record when lightning is first seen or thunder heard. At lookout stations and others having unrestricted visibility, consider only those thunderstorms occurring within 30 miles of the observation station.

35 *Lightning Activity Level.* Complete in accordance with NFDR instructions.

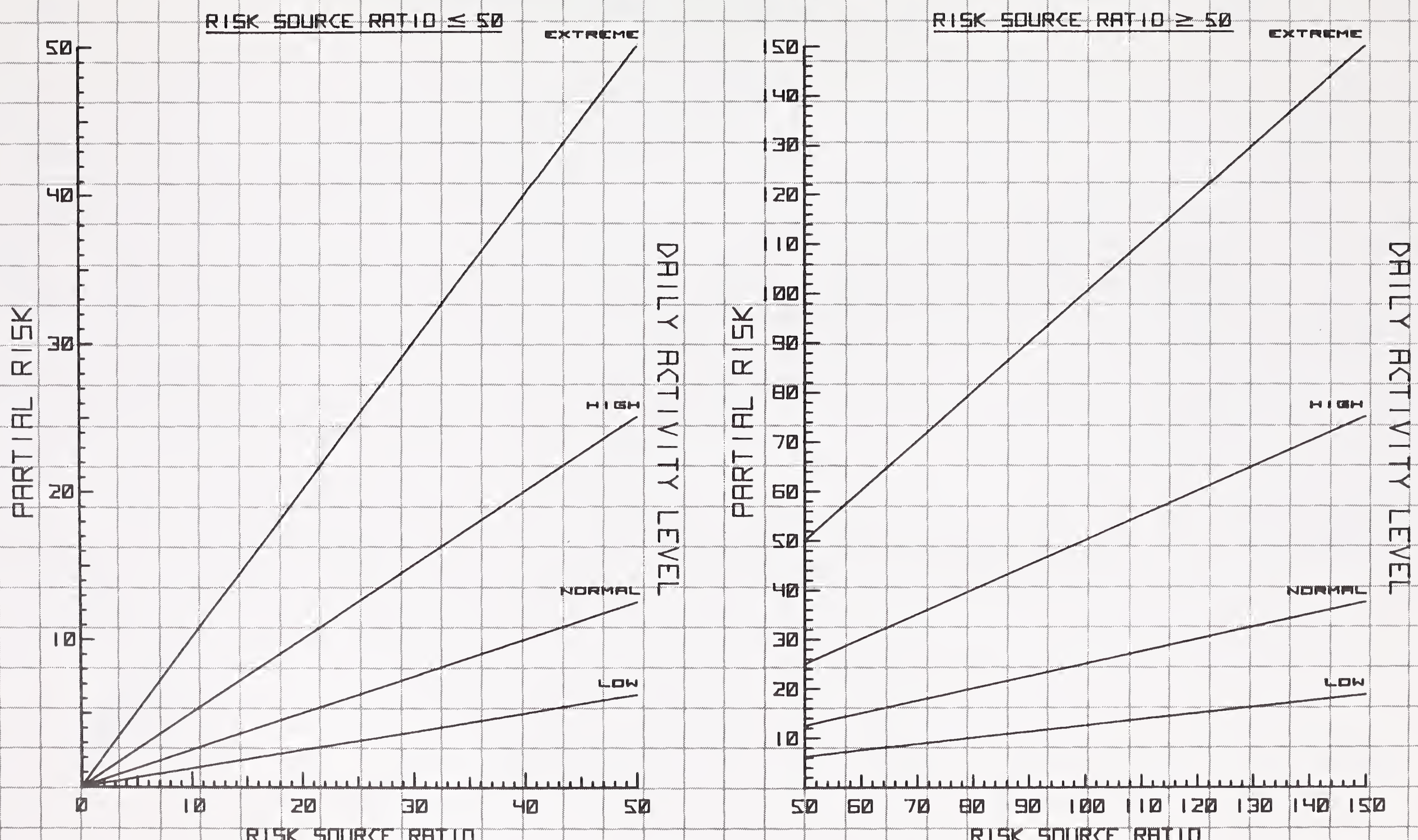
36 *100-h Timelag Fuel Moisture.* Assume 30 percent for an initial 100-h timelag fuel moisture value in the spring. The "yesterday's" 100-h timelag fuel moisture input is the 100-h timelag fuel moisture from the previous day entry (col. 36). Compute using the NFDR nomogram.

37 *Today's 1,000-h BNDRY Value.* Compute using the appropriate NFDR nomogram.

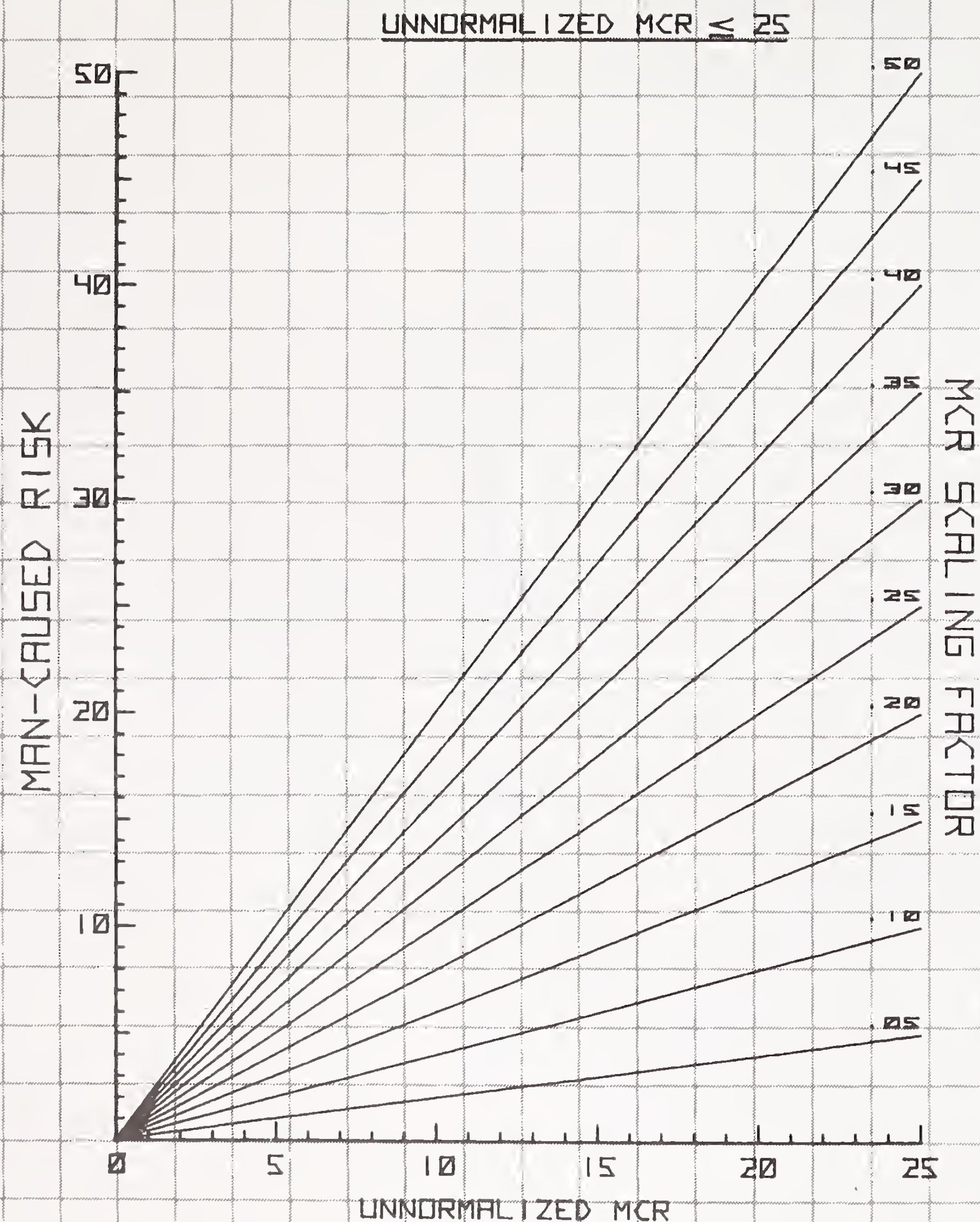
Column number	COLUMN INSTRUCTIONS
38	*Average 7-day 1,000-h BNDRY Value.* Compute by summing the current day's and the previous 6 days' 1,000-h BNDRY values and divide by 7.
39	*Change in 1,000-h Timelag Fuel Moisture.* Compute using the appropriate NFDR nomogram. Record the change as positive (+) or negative (-). The "prior 7-day 1,000-h timelag fuel moisture" is the last entry in col. 40.
40	*1,000-h Timelag Fuel Moisture.* Compute by adding the (+) or (-) change in 1,000-h timelag fuel moisture from col. 39 to the previous 1,000-h timelag fuel moisture value in col. 40.
41	*Woody Fuel Moisture.* Compute using the appropriate NFDR nomogram.
42 & 43	*X1000 Moisture Value and Herbaceous Fuel Moisture.* The X1000 moisture value assumes the 1,000-h timelag fuel moisture value at the time herbaceous greenup occurs (triggered by herbaceous vegetation condition (col. 9)). Compute the X1000 value from the NFDR nomogram using the previous 7-day X1000 moisture value. Herbaceous fuel moisture is computed for annual or perennial vegetation from an NFDR nomogram.
A - D	These columns may be used for supplemental data, predictions, and so on.

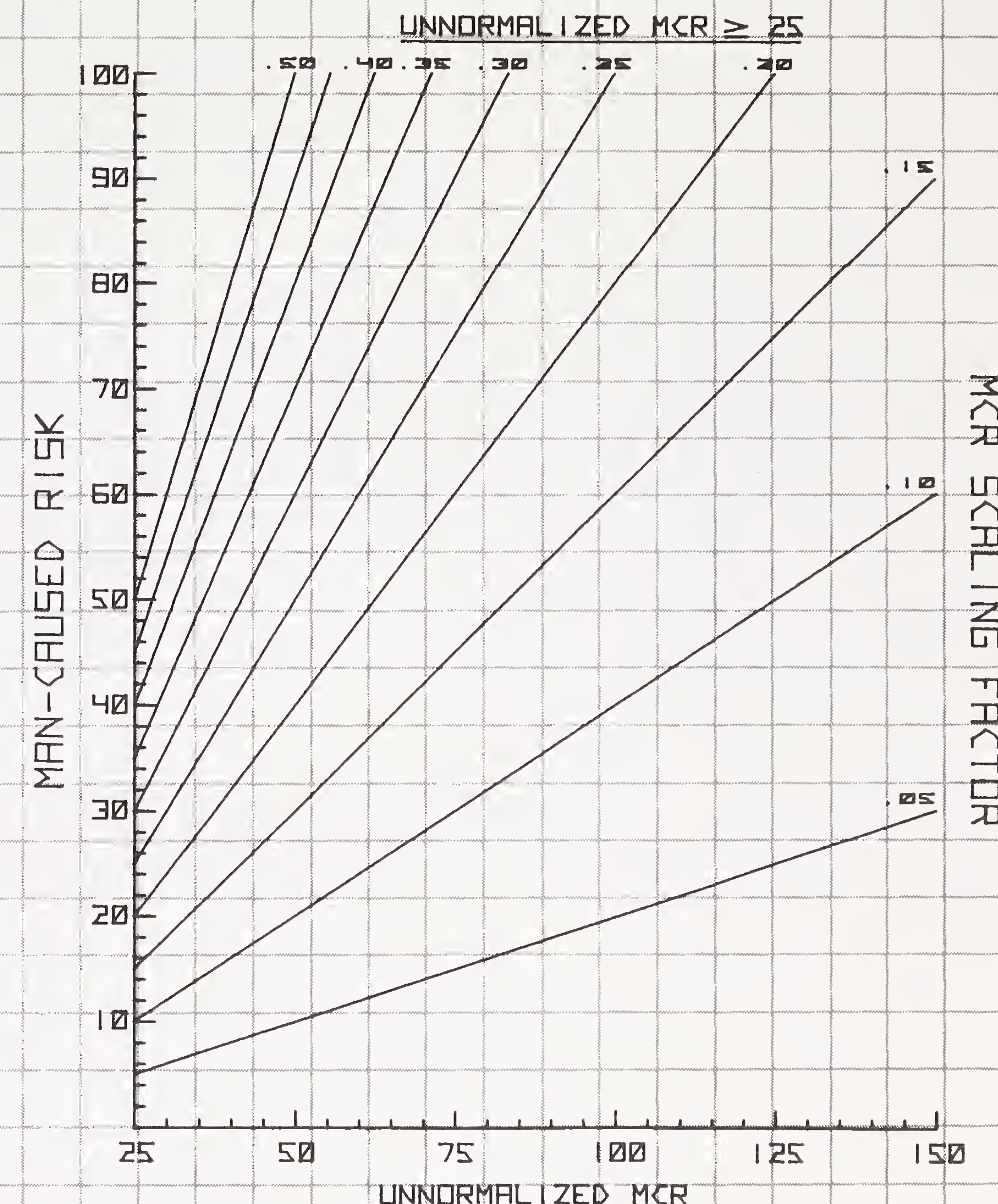
*If observations for a day are missed, estimate them using any available information. Explain under "Remarks."

PARTIAL RISK

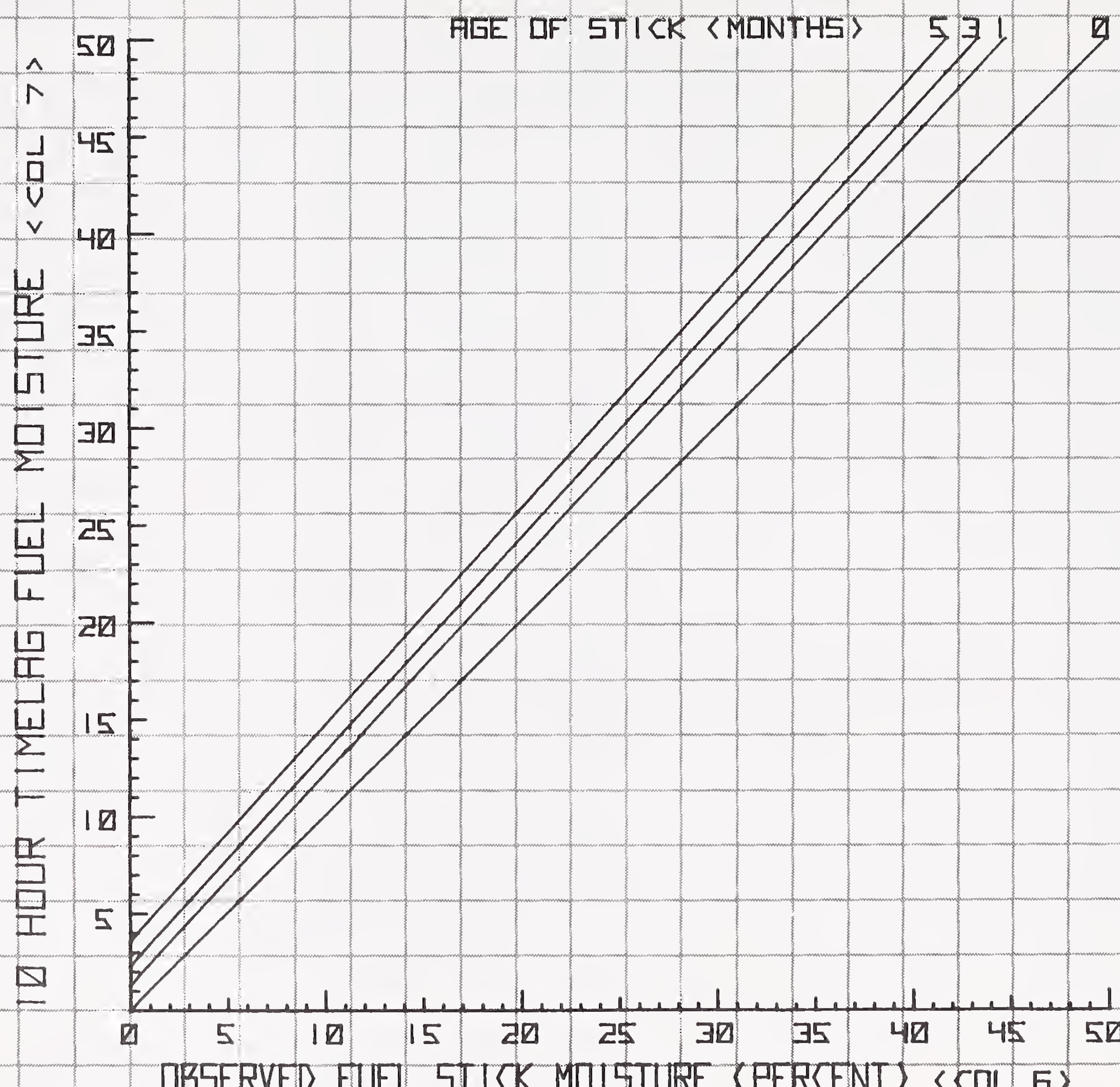


MAN-CAUSED RISK





10 HOUR TIMELAG FUEL MOISTURE



ERRATA SHEET

USDA Forest Service General Technical Report INT-39

The National Fire Danger Rating System - 1978
by Deeming, Burgan, and Cohen

- Page 11--There are blanks in the first five lines of the third paragraph. Complete these lines with the following:

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  fire danger
  information
  may be
  24

- Page 47--In the second line under <u>Guideline E</u>, "column 18" should read "column 19".

- Page 49--In Table 9 there are 3 changes:

  In the fifth line under the heading <u>Narrative</u>, "for control" should read "for direct control".

  In the fourth line under the heading <u>Burning index</u>, "96" should read "92".

  In the fourth line under the heading <u>Flame length</u>, "9.6" should read "9.2".

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The results of this work are presented in two publications. This publication covers the general information on the NFDRS and its application; a second publication (Burgan and others 1977) contains the nomograms and directions for calculating fire-danger ratings manually.

KEYWORDS: fire-danger rating, danger rating meters, burning index, fuel moisture content, lightning, man-caused forest fires, fire weather.

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1977-0-777-023/37

NATIONAL
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